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# THE ECONOMICS OF CLEAN WATER. VOLUME I.

Environmental Protection Agency
Washington, D. C.

1972

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# THE ECONOMICS OF CLEAN WATER

## VOLUME I

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1972

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ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF THE ADMINISTRATOR

APR 27 1972

Honorable Spiro T. Agnew
President of the Senate
United States Senate
Washington, D. C. 20510

Dear Mr. President:

I am transmitting to the Congress the fifth annual report on the national requirements and costs of water pollution control as required under Section 26(a) of the Federal Water Pollution Control Act, as amended.

The enclosed report entitled The Economics of Clean Water represents our current estimates of the investment levels necessary to meet applicable water quality objectives in both the municipal and industrial sectors.

Volume I, The Report, describes the analyses and surveys which were undertaken to arrive at our current investment estimates. This analysis included an industrial cost model which was used to estimate required industrial investment and a detailed study of available data on industrial water use trends. The amount of planned construction for municipal waste water facilities obtained by a survey and a statistical model using municipal data is presented. The volume also contains the water pollution index for estimating the condition of the nation's waters and an evaluation of benefits and costs of various waste treatment levels from a national point of view.

Volume II, Data and Technical Appendices, provides the basic input and output data for the industrial facilities evaluation model as well as a description of the model itself. It includes the method and data used for the pollution index and the procedure used for the survey of planned construction of municipal waste treatment facilities.

Volume III, Industry Expenditures for Water Pollution Abatement, is the report by the Conference Board of a survey undertaken to provide detailed information on the industrial view of water pollution control costs.

A fourth part is a summary of major findings and conclusions of the analysis contained in this report.

Sincerely yours,

William D. Ruckelshaus

William D. Ruckelshaus
Administrator

Enclosure

ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF THE ADMINISTRATOR

APR 27 1972

Honorable Carl B. Albert
Speaker of the House
of Representatives
Washington, D. C. 20515

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# INTRODUCTION

This report represents the fifth in the series of clean water reports to the Congress prepared in accordance with Section 26(a) of the Federal Water Pollution Control Act, as amended.

Part I of this volume contains an assessment of the prevalence and degree of water pollution occurring nationally and compares the 1971 results with those of 1970. This is a tentative estimate, and EPA plans to considerably improve the quality of its water pollution trend analysis in 1972.

Because of the increasing importance of capital requirements associated with industrial waste treatment, this report presents in Part II industrial trends in water use, discharge, and treatment and an estimate of the capital investment requirements through 1976.

The results of the recent municipal needs survey are reported in Part III along with an estimate of needs statistically derived from the facilities evaluation model developed last year (Cost of Clean Water, March 1971, Volume II). In addition, the ability of the construction industry to construct the needed treatment works is examined.

# WATER POLLUTION IN 1971

## Introduction

This section describes a procedure that is being developed by EPA for evaluation of water pollution. The indexing procedure allows any waterbody or set of waterbodies to be described with respect to water pollution characteristics. Data on the prevalence of pollution for this index has been collected for the years 1970 and 1971.

A further development of this index is to include duration and intensity of water pollution as factors in describing waterbodies. Such data were collected for the first time in 1971. These results show that pollution varies from region to region and is a response to geographical as well as economic circumstances.

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## Methodology Used to Calculate Index

The Environmental Protection Agency is continuing its effort to develop a comprehensive measure of relative water quality. It has developed internally a procedure for measuring not water quality in the absolute, but deviations from established standards of water quality.

### Water Quality Standards

Interstate water quality standards are the basis of the definition of the condition of pollution.

The water quality standards are a three-fold device that established for discrete stream reaches: (1) a statement of the uses of water that are physically and chemically possible in nature and which are desired by the users and potential users of those waters, (2) a definition--generally in quantitative terms--of the physical, chemical, and biological conditions that are minimally consistent with those uses (subject to the general constraint that where one or more of those conditions were superior to the scientifically-determined minimum at the time the standards were developed, the existing quality of the waters in question would constitute the acceptable minimum for such parameters), and (3) a plan for meeting water quality criteria.

The "water pollution index" addresses only the first two of the three elements of the standards. It is concerned with observable, verifiable environmental fact rather than legal, regulatory, administrative, or technological arrangements of implementation plans.

## Comparison to Standards--Prevalence of Pollution

The basic element of the index is a simple measurement or judgement. Once standards have been determined for a set of water quality parameters, the procedure calls for a comparison of those standards with measured quality. Where any variable or combination of variables do not meet or exceed the standard, then a state of pollution exists--by definition.

This rather rudimentary test was first applied in 1970, when a ratio of polluted waters to total waters was established for the nation, using the simple formula:

$$\frac{P}{M} = \text{prevalence of pollution}$$

Where P = number of stream and shoreline miles in which one or more of the established chemical and biological criteria had not been met one or more times.

M = total stream and shoreline miles, to and including third-order tributaries

## 1970 Results

The assessment of the prevalence of pollution made in 1970 indicated that almost 27 percent of America's stream miles were polluted.[1]

## 1971 Results

Measuring the prevalence of pollution alone (which excludes duration and intensity factors; cf. Table 1), it appears that water pollution increased from 1970 to 1971. While the 1970 assessment indicated that water quality criteria violations occurred over almost 70,000 stream miles, the assessment in 1971 suggested that more than 76,000 stream miles did not conform to water quality criteria. In terms of relative prevalence, pollution extended from 26.8 percent of the nation's waters to 29.3 percent.

In point of fact, the assessed prevalence of water pollution in 1971 may understate the amount of the increase. Several States of the Upper Mississippi Basin and the Southwest have included in their water quality standards exceptions for conditions due to precipitation. The 1970 evaluation of stream conditions took into account only in-stream violations of water quality criteria, without making the stipulated allowance for source. On the other hand, the addition of stream miles predominantly polluted by acid mine drainage in the Ohio Basin would tend to overstate the increase since they were not assessed in 1970.

## Regional Variation in Pollution Prevalence

Every part of the nation has some water pollution, but the shares are very unevenly distributed. There were in 1971 almost twice as many polluted stream miles east of the Mississippi River as west of it.

When viewed from the standpoint of the ten Federal Administrative Regions, as presented in Table 1, pollution was more than five times as common in the Chicago Region as in the Kansas City Region. (It should be noted, however, that the Kansas City Region is one where assessment is heavily

---

[1] As originally reported in Cost Effectiveness and Clean Water, the value was given as 31.2 percent. Continuing analysis of the data indicated that: (1) length of minor tributary streams was under-reported in the aggregate and (2) overlapping administrative boundaries caused double-counting of polluted miles in some cases. When adjusted for these factors, reported prevalence of pollution dropped to 26.8 percent.

## TABLE 1

## PREVALENCE OF STREAM QUALITY CRITERIA VIOLATIONS--1971

| EPA Region | Stream and Shoreline Miles | Miles of Criteria Violation | Percent of Miles Polluted | Percent of Total U.S. Miles | Percent Polluted Miles |
|---|---|---|---|---|---|
| I Boston | 29,701 | 4,869 | 16.4 | 11.4 | 6.4 |
| II New York | 4,889 | 2,071 | 42.4 | 1.9 | 2.7 |
| III Philadelphia | 24,311 | 8,437 | 34.7 | 9.3 | 11.1 |
| IV Atlanta | 39,125 | 14,840 | 37.9 | 15.0 | 10.4 |
| V Chicago | 28,769 | 18,569 | 64.5 | 11.1 | 24.3 |
| VI Dallas | 46,646 | 10,010 | 21.5 | 17.9 | 13.1 |
| VII Kansas City | 19,189 | 2,396 | 12.5 | 7.4 | 3.1 |
| VIII Denver | 22,693 | 5,688 | 25.0 | 8.7 | 7.4 |
| IX San Francisco | 16,693 | 3,956 | 23.5 | 6.5 | 5.2 |
| X Seattle | 28,166 | 5,477 | 19.4 | 10.8 | 7.2 |
| Contiguous U. S. | 260,324 | 76,299 | 29.3 | 100.0 | 100.0 |
| East of Mississippi River | 126,795 | 48,777 | 38.5 | 48.7 | 63.9 |
| West of Mississippi River | 133,529 | 27,522 | 20,6 | 51.3 | 36.1 |

affected by the exclusion of stream quality criteria violations traceable to precipitation.) While the Chicago Region was the only one in which polluted natural waters were more common than unpolluted, more than a third of the waters of the New York, Philadelphia, and Atlanta Regions were found to be polluted during 1971.

## Comparison to Standards
## Duration and Intensity of Pollution--Incidence

An assessment of pollution in terms of mere prevalence is essentially unsatisfactory--rather like equating cancers, chronic appendicitis, and the common cold in an assessment of health conditions. Degree of pollution and its persistence are significant dimensions of the phenomenon--perhaps the more significant, given the range of uncertainties that attach to the water quality criteria. EPA is developing the pollution index to include such factors.

The water pollution index, using 1971 data, takes these factors into account by establishing separate weighting values to a circumstance of pollution, according to its seasonal characteristics and its interference with uses sanctioned by the water quality standards. The simple formula for determining the prevalence of pollution becomes only slightly more complex, but the level of effort and judgement required to apply the formula is increased enormously:

$$\frac{P \cdot D \cdot I}{M} = \text{Water Pollution Index}$$

Where D = a factor ranging from 0.4 to 1.0 to express the inter-seasonal duration of pollution.

I = a factor ranging from 0.1 to 1.0 to express the intensity of water pollution in terms of damage.

(An explanation of these variables is contained in the Technical Appendix [Volume II of this report].)

When reach-by-reach pollution conditions are weighted to give expression to duration and intensity an index is formed which provides a consistent measurement of unequal variables against a common base--in this case, the water quality standards.

### Relationship of the Duration-Intensity Factors to Prevalence of Pollution--1971

The relative water pollution standing of Federal Administrative Regions is not significantly changed when the frame of reference shifts from simple prevalence of pollution to an index of prevalence weighted by relative duration and severity (cf. Table 2).

## TABLE 2

## RELATIVE INCIDENCE OF WATER POLLUTION

| EPA Region | Percent Of Stream Miles Polluted | Duration Intensity Factor | Duration-Intensity As a Percent of U.S. Mean | Percent Polluted U.S. Miles |
|---|---|---|---|---|
| I Boston | 16.4 | .62 | 151 | 6.4 |
| II New York | 42.4 | .45 | 110 | 2.7 |
| III Philadelphia | 34.7 | .58 | 141 | 11.7 |
| IV Atlanta | 37.9 | .45 | 110 | 19.4 |
| V Chicago | 64.5 | .43 | 105 | 24.3 |
| VI Dallas | 21.5 | .37 | 90 | 13.1 |
| VII Kansas City | 12.5 | .33 | 81 | 3.1 |
| VIII Denver | 25.0 | .23 | 56 | 7.4 |
| IX San Francisco | 23.5 | .20 | 49 | 5.2 |
| X Seattle | 19.4 | .11 | 27 | 7.2 |
| Contiguous U. S. | 29.3 | .41 | 100 | 100.0 |
| East of Mississippi River | 38.5 | .48 | 117 | 63.9 |
| West of Mississippi River | 20.6 | .28 | 68 | 36.1 |

In general, the greater the prevalence of water pollution, the higher the aggregated duration-intensity factor. There are, however, exceptions. The Boston Region--that is, the New England States--is second only to the Kansas City Region with respect to the portion of its waters that is not polluted; but it is the worst region in the nation with respect to persistence and damage. The Denver Region, which stands fifth among the ten administrative regions in extensiveness of pollution, is a creditable ninth with respect to duration and intensity. And though the Chicago Region has the worst pollution index, it is largely because it has the highest prevalence of pollution, since it is no worse than fifth in terms of persistence and damage.

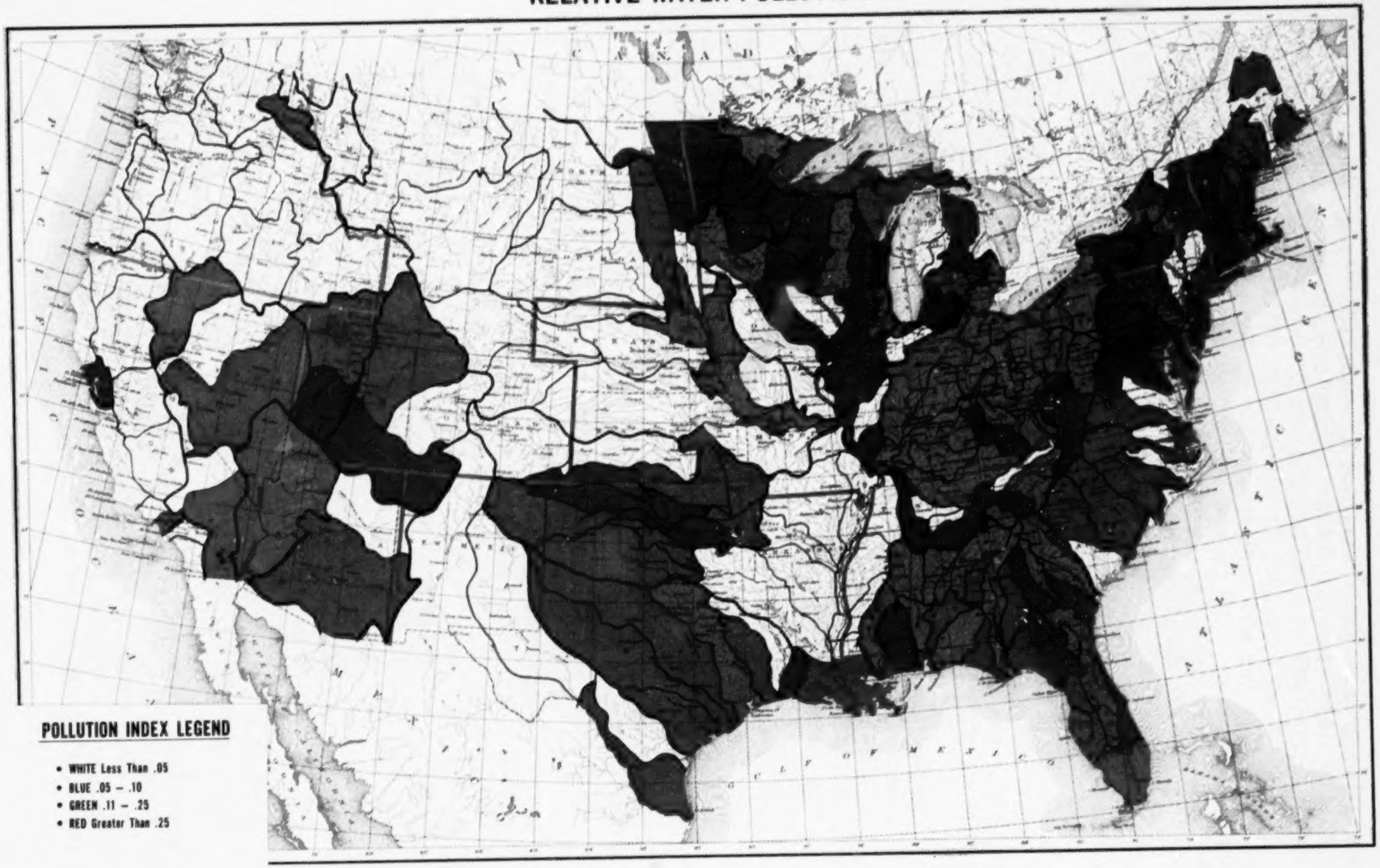
These distributional features become more apparent when the categorical focus is shifted from political to natural boundaries. For comparative purposes, then, the discussion from this point will be framed in terms of nine sets of physical drainage areas (cf. Figure 1):

1. "The Northeast Basins" is composed of those watersheds that drain directly to the Atlantic from the Canadian border on the north to the drainage area of Chesapeake Bay on the south;
2. "The Middle Atlantic Basins" comprises drainage to the Atlantic from Chesapeake Bay southward to the drainage of the Santee River;
3. "The Southeastern Basins" consists of the drainage to the Atlantic from the Santee River southward, the east bank drainage to the Mississippi from the Tennessee River southward, and direct drainage to the Gulf of Mexico east of the mouth of the Mississippi;
4. "The Great Lakes Basins" consists of the drainage of the Great Lakes and the St. Lawrence River;
5. "The Ohio Basin" is the area drained by the Ohio River;
6. "The Missouri River Basin" consists of the drainage area of the Missouri and the Souris-Red-Rainy systems, as well as direct western discharges to the Mississippi River north of the confluence with the Missouri River;
7. "The Gulf Basins" consists of the west bank discharges to the Mississippi River that occur south of the drainage of the Missouri, together with direct discharges to the Gulf of Mexico that occur west of the Mississippi River;
8. "The California Basins" includes the area drained by all discharges to the Pacific Ocean south of the Oregon-California border, together with discharges to the Gulf of California and the closed watersheds of the Great Basin; and
9. "The Columbia North Pacific Basins" includes the area drained by the Columbia River and all direct discharges to the Pacific Ocean between the Canadian and California borders.

When the pollution index data are framed in these hydrologic terms, the degree to which water pollution is concentrated becomes more evident. The three broad hydrologic groupings for which both the prevalence factor and the duration-intensity factor are above the national mean include 48 of the 61 second-order watersheds in which

FIGURE I

RELATIVE WATER POLLUTION


CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
POLLUTION INDEX LEGEND
• WHITE Less Than .05
• BLUE .05 – .10
• GREEN .11 – .25
• RED Greater Than .25

more than half of all stream and shoreline miles are reported to be polluted. The same three (Ohio, Southeast, Great Lakes) also include 79 of the 113 second-order watersheds in which aggregated duration-intensity factors exceed the national value. Among them, they include 23.9 percent of the nation's stream miles (third-order streams or greater), but 48.9 percent of the polluted stream miles.

The smaller the units of the hydrologic system that are considered, the more apparent it becomes that water pollution may be far more concentrated than is generally supposed. Table 3 provides a demonstration of that fact. It arranges the 241 first-order tributaries of the nine broad, synthetic hydrologic groupings in class intervals according to prevalence of pollution and duration-intensity. The table makes it clear that extensive pollution is very nearly limited to the Ohio, Great Lakes, and Southeastern drainage systems. And though the Northeastern watersheds are in a class with the other three with respect to duration and intensity of pollution, they tend to dominate that measure as well.

Thus the median class interval for prevalence of pollution is:

21-30 percent of stream and shoreline miles for the U.S.
81-90 percent for the Ohio River Basin,
21-30 percent for the Southeastern Basins,
41-50 percent for the Great Lakes Basins, and
11-20 percent for the rest of the nation.

Similarly with respect to duration-intensity of pollution, where the median is:

.410 - .509 for the nation,
.410 - .509 for the Ohio River Basin,
.610 - .709 for the Southeastern Basins,
.410 - .509 for the Great Lakes Basins, and
.310 - .409 for the rest of the nation.

It is not appropriate to compare 1970 and 1971 conditions of water pollution on the basis of the separate national assessments. The quality of the 1971 survey was far superior to its predecessor, due largely to the facts that an informational and experiential base was established by the 1970 survey that resulted in an improved second effort, and that a more rigorous methodology was imposed on the assessors in 1971. Further, the 1971 assessment included provision for the duration and intensity factors that go into the water pollution index.

A comparison of the common factor of prevalence, however, can be made. Such an evaluation is summarized by major drainage area in Table 4. In general, the major drainage areas with the higher prevalence of pollution in 1970 became even worse in 1971.

## TABLE 3

## DISTRIBUTION OF POLLUTION BY MAJOR DRAINAGE AREAS

| Percent of Stream Miles Polluted | Number of Tributary Basins<br>Ohio | South East | Great Lakes | North East | Middle Atlantic | California | Gulf | Missouri | Columbia | U.S. | Percent of U.S. Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | 1 | 1 | 1 | | 3 | | 3 | 1 | 10 | 4.2 |
| 1-10 | | 10 | 7 | 9 | 5 | 5 | 6 | 6 | 2 | 50 | 20.8 |
| 11-20 | | 5 | 4 | 6 | 8 | 6 | 15 | 3 | 5 | 52 | 21.6 |
| 21-30 | | 4 | 9 | 6 | | 1 | 6 | 2 | 5 | 33 | 13.7 |
| 31-40 | 2 | 5 | 3 | 3 | 1 | 2 | 2 | 1 | 1 | 20 | 8.3 |
| 41-50 | 2 | 4 | 4 | 1 | | 1 | 2 | 1 | | 15 | 6.2 |
| 51-60 | | 1 | 3 | 4 | | 2 | | | | 10 | 4.2 |
| 61-70 | 3 | 4 | 5 | | | 4 | | 1 | | 17 | 7.1 |
| 71-80 | 3 | 2 | 5 | | | | | | | 10 | 4.2 |
| 81-90 | 2 | 1 | 2 | 1 | | 1 | | | | 7 | 2.9 |
| 91-100 | 9 | 2 | 6 | | | | | | | 17 | 7.1 |
| Total | 21 | 39 | 49 | 31 | 14 | 25 | 31 | 17 | 14 | 241 | 100.0 |
| Prevalence Factor | .84 | .38 | .41 | .18 | .17 | .29 | .17 | .17 | .19 | .29 | |
| Duration-Intensity Factor | .42 | .74 | .45 | .61 | .47 | .27 | .35 | .37 | .12 | .41 | |
| 0 -.109 | | 1 | 3 | 1 | | 6 | 1 | 6 | 9 | 27 | 11.2 |
| .110-.209 | 1 | | 2 | | | 8 | 12 | 2 | 3 | 28 | 11.6 |
| .210-.309 | 2 | 1 | 8 | 3 | 2 | 5 | 4 | 2 | | 27 | 11.2 |
| .310-.409 | 7 | 2 | 3 | 2 | 2 | 3 | 5 | 5 | 2 | 31 | 12.9 |
| .410-.509 | 3 | 2 | 11 | 4 | 8 | 1 | 4 | 1 | | 34 | 14.1 |
| .510-.609 | 4 | 5 | 4 | 5 | 2 | | 3 | | | 23 | 9.5 |
| .610-.709 | 3 | 10 | 3 | 5 | | 1 | 1 | | | 23 | 9.5 |
| .710-.809 | 1 | 12 | 6 | 8 | | 1 | | | | 28 | 11.6 |
| .810-.909 | | 4 | 6 | 3 | | | 1 | 1 | | 15 | 6.2 |
| .910-1.00 | | 2 | 3 | | | | | | | 5 | 2.1 |

## TABLE 4

## WATER POLLUTION INDEX SUMMARIZED FOR MAJOR DRAINAGE AREAS, 1970 AND 1971

| Major Watershed | Stream Miles | Polluted Miles | | | 1971 D.I. Factor |
|---|---|---|---|---|---|
| | | 1970 | 1971 | Change | |
| Ohio | 28,992 | 9,869 | 24,031 | +13,746 | .42 |
| Southeast | 11,726 | 3,109 | 4,490 | + 1,381 | .74 |
| Great Lakes | 21,374 | 6,580 | 8,771 | + 2,191 | .45 |
| Northeast | 32,431 | 11,895 | 5,823 | - 6,072 | .61 |
| Middle Atlantic | 31,914 | 4,620 | 5,627 | + 869 | .47 |
| California | 28,277 | 5,359 | 8,429 | + 2,499 | .27 |
| Gulf | 64,719 | 16,605 | 11,604 | - 5,001 | .35 |
| Missouri | 10,448 | 4,259 | 1,839 | - 2,420 | .31 |
| Columbia | 30,443 | 7,443 | 5,685 | - 1,758 | .12 |
| U. S. | 260,324 | 69,739 | 76,299 | + 5,435 | .41 |
| U. S. Less Ohio | 231,332 | 59,870 | 52,268 | - 8,311 | .40 |
| U. S. Less Columbia | 229,881 | 62,296 | 70,614 | + 7,193 | .43 |

Unfortunately, of the four apparently significant shifts in reported water pollution that took place--in the Ohio, Gulf, Missouri, and Northeastern Basins--three are so obscured by variations in procedure that it is difficult to evaluate the degree of real change. Both the Gulf and the Missouri Basins reported an enormous improvement in compliance with water quality standards. But in each case, the 1970 assessment failed to make allowance for legally sanctioned breaches of water quality criteria that resulted from precipitation; and in either case, that exception is a significant matter. Apparent improvement, then, can only be ascribed with assurance to compliance with a legal standard, not to better water. And in the case of the Ohio River Basin, the 1970 assessment concentrated on the quality of major waterbodies, overlooking smaller tributaries. But in the Ohio, a phenomenon that is almost unknown elsewhere is common, in that many streams are polluted at the source as a result of the acid drainage of mountain coal mines. Of twenty-one river systems in the Ohio River Basin, nine--the Little Miami, the Licking, the Miami, the Kentucky, the Salt, the Green, the Wabash, and the East and West Forks of the White--are in violation of water quality criteria over their total span during at least part of each year. Three others--the Guyandot, the Hocking, and the Cumberland--have only a few miles free of pollution. Failure to account for this total prevalence of pollution in 1970 is at least partially responsible for the increase in reported pollution in 1971.

On the basis of the data available, if data anomalies are overlooked, we may conclude that substantially the same number of river miles was polluted in 1971 as in 1970 and that the western States had less water pollution and less severe water pollution than eastern States. (The evaluation holds for changes in the water quality of discrete river systems as well as for gross hydraulic groupings (cf. Table 5).[2] In coming years as comparable data is developed, the water pollution index will be able to better identify trends in pollution for the nation.

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[2] Appendix--presents instructions for calculating the pollution indices, and index data summarized for second-order watershed.

# TABLE 5

## SHIFTS IN PREVALENCE OF POLLUTION SUMMARIZED FOR MAJOR DRAINAGE AREAS, 1970 AND 1971

| | Number of Tributary Basins[1] | | |
|---|---|---|---|
| | Pollution Increased | Unchanged (± 10 Percent) | Pollution Decreased |
| Ohio River Basin | 18 | 1 | 0 |
| Southeastern Basins | 13 | 24 | 1 |
| Great Lakes Basins | 25 | 5 | 18 |
| Northeast Basins | 5 | 5 | 18 |
| Middle Atlantic Basins | 5 | 2 | 5 |
| California-Colorado-Closed Basins | 11 | 4 | 9 |
| Gulf-Southwest Basins | 4 | 6 | 20 |
| Missouri Basin | 3 | 1 | 12 |
| Columbia-North Pacific Basins | 4 | 2 | 8 |
| U. S. | 88 | 50 | 91 |

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[1] 1970 Data not available in all cases.

# I

# TRENDS IN INDUSTRIAL WATER USE--DISCHARGE AND TREATMENT

## Introduction

The chapter traces quantitatively trends in manufacturing use of water between 1959 and 1968, concentrating on growth of discharge volume, rates, and waste treatment, and relating them to changes in the institutional setting.

## Summation

Industrial water intake and discharge is increasing at a less pronounced rate than industrial output. The proportion of industrial wastewater discharge that is treated continues to grow, and amounted to 37 percent of discharge in 1968. Waste treatment growth was less between 1964 and 1968 (3.1 percent annual rate of increase), however, than between 1959 and 1964 (10.5 percent annual rate of increase). Most of the increase in industrial waste treatment occurred at the factory. For, although use of public sewers and waste treatment plants is the main method of waste disposal for a number of manufacturing sectors, the portion of industrial effluent discharged to public facilities dropped from almost 9 percent in 1959 to little more than 7 percent in 1968.

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## TRENDS IN INDUSTRIAL WATER USE--DISCHARGE AND TREATMENT

Publication of Water Use in Manufacturing, 1967 permits a survey of trends over the period 1959 to 1968 and re-examination of findings reported in Volume II of the Cost of Clean Water for 1967. Also available for analysis of industrial practices with respect to handling of liquid-borne wastes is a recent survey conducted by the Conference Board. Under the sponsorship of the Federal Water Quality Administration, the Conference Board (formerly the National Industrial Conference Board) conducted a survey of establishments in the seven heaviest water-using manufacturing groups.[1] From the almost 800 responses, a number of significant findings emerged.

### The Institutional

Important changes in institutions and attitudes with respect to industrial waste discharges, and discharge of pollutants generally, occurred during the sixties. Amendments to PL 660 (the Federal Water Pollution Control Act) in 1966 required the States, in consultation with all users of interstate waterways and to the satisfaction of the Secretary of the Interior, to set standards for interstate waterways. The standards were to account for all uses of the waterwasy except as a medium for the disposal of wastes. Negative sanctions for dischargers, including industrial dischargers, who violated the standards were also developed. As a consequence of State and Federal efforts to attain, or in some cases maintain, water quality standards, a large number of industrial dischargers have indicated they will comply with the standards by installing treatment measures, altering processes, or curtailing pollutant-generating activities. Prior to the promulgation of water quality standards, a number of States had some kind of pollution surveillance and enforcement program. These provide an indication of the differences in intensity of water pollution control activities between the first and second half of the sixties. Man-years of such programs in the United States grew at an annual rate of 3.3 percent from 1959 to 1964, but from 1964 to 1968 the annual rate of growth was 13.4 percent; and since 1968 the annual rate of growth has been almost 21 percent. Assuming that there is a positive correlation between effectiveness of a program and the resources allocated to it, the growth in State water pollution control activities has provided an additional impetus to curtailment of waste discharges by industries.

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[1] The industry groups surveyed were Food and Kindred Products (SIC 20), Textile Mills Products (SIC 22), Paper and Allied Products (SIC 26), Chemical and Allied Products (SIC 28), Petroleum and Coal Products (SIC 29), Rubber and Plastics Products (SIC 30), and Primary Metals (SIC 33).

Amendments to the Water Pollution Control Laws during the last decade have increased both the amount of federal funds devoted to municipal wastewater treatment works and the federl share of the total funds. To the extent that local communities are primarily interested in recovery of local out-of-pocket costs rather than total system costs from those connected to the system, the increased federal share and funding levels represent an increase in subsidies to connected industrial establishments. This added incentive to treat wastes should have resulted in increased industrial connections to municipal treatment works, and, presumably, more adequate treatment of industrial wastes.

Continued pressures on existing supplies of freshwater, both surface and ground, have, in a large portion of the continental United States, increased the cost of obtaining additional units of water suitable for industrial application. In order to obtain additional units of water, industry has had to turn to poorer quality water, such as brackish water or treated sewage effluent, and to sink deeper wells. In effect, the price to industry of obtaining water has generally increased during the last decade and has provided an incentive to economize on water intake. Process change, including recycling, directed towards more efficient use of water cah have a number of benefits. Process changes may decrease the amount of water-borne residuals per unit of product produced. Industrial recycling and reuse of water will often result in a highly concentrated end-of-stream effluent which generally eases the problems of waste handling and disposition, and can make by-product recovery a profitable activity. In addition to the problem of increasing pressures on available supplies of freshwater, the Northeastern drought of the early 'sixties has probably brough the necessity for planning for adequate industrial water supplies into many capital budgeting decisions. In fact, a study of the response of local government and industry to the Northeastern drought in the State of Massachusetts indicates that industry primarily adjusted to the situation by investing in equipment to recirculate water--almost 70 percent of the reported investments to adjust to the drought were for recirculation facilities.[2]

One additional change in the climate in which decisions concerning ultimate dispostion of industrial waste discharges were made is the increased public relations value to a firm of industrial pollution control measures. In the late 'sixties environmental and consumer issues received considerable attention from citizens and politicians. This concern has increased the value to a firm of installing and publicizing a pollution control facility.

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[2] Clifford S. Russell et al., Drought and Water Supply (Johns Hopkins Press, 1970), p. 110.

Although all of the above developments might be expected to provide an incentive to industry to curtail and treat liquid-borne wastes, other trends mitigate against reduction in the discharge of industrial pollutants. The sheer growth of manufacturing output and the associated production of residuals continues to create waste handling problems. Over the period 1959-1968 the Federal Reserve Board Index of Industrial Production for manufacturing increased 59 percent, and for the five major water-using industries--food products, paper, chemicals, petroleum, and primary metals--the index grew by 29, 48, 94, 33 and 52 percent, respectively. In addition to water demand growing directly out of production growth, industry's continued accumulation of capital created both a direct demand for cooling water and indirect demand by increasing the consumption of thermally generated power used by industry.

In summary, a number of economic and institutional changes in the last decade lead to the expectation that incentives have been provided for industry to curtail and treat liquid-borne wastes. Offsetting these incentives are growth of production and consequent residuals production.

## Industrial Water Use and Discharge 1959-1968

According to the Water Use in Manufacturing, 1967 14,276 billion gallons of wastewater were discharged in 1968 by manufacturing establishments using 20 million gallons of water or more. The 1968 figure represents an 8.5 percent increase over 1964 and 24.7 percent increase over 1959. However, as Tables 1 and 2 indicate, discharge across the nation and for most industries over the period 1959 to 1968 grew at a slower rate than did value added (in constant dollars), as is also the case for most of the industrial water use regions.

For those industries for which this was not the case the following observations can be made. Data anomalies result from industry concentration which leads to fewer and larger firms with a higher number of establishments in the over 20 MGY category. Some industries using lower grade raw materials have more need for residuals elimination and some could have operations at a lower percent of capacity on a more heavily capitalized base.

Estimates of industrial production of $BOD_5$ presented in the 1971 Cost of Clean Water[3] indicated that this component of total waste produced increased by 97 percent between 1957 and 1968, though, of course, a significant portion of this load was withheld from surface water bodies through treatment.

The geographical incidence of industrial waste discharges in 1968 is shown in Table 3. Not surprisingly, the industrial Northeast and Midwest are the largest repositories of industrial discharges, with the Western Gulf area also receiving a significant portion. The industrial sources of discharges within regions are indicated in Table 4.

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[3] U. S. Environmental Protection Agency, Water Quality Office, Cost Effectiveness and Clean Water (1971), p. 29.

## TABLE 1

## INDUSTRIAL WASTEWATER DISCHARGE AND VALUE ADDED BY INDUSTRIAL WATER USE REGIONS, 1959-68

| Industrial Water Use Region | Total Industrial Wastewater Discharges, 1968 (Billions of Gal.) | 1968 Industrial Wastewater Discharge as a Percentage of 1959 Discharge | 1968 Value Added (Deflated) as a Percentage of 1959 Value Added |
|---|---|---|---|
| New England | 558.4 | 113.0 | 131.6 |
| Delaware and Hudson | 1191.9 | 98.1 | 114.6 |
| Chesapeake Bay | 754.7 | 133.8 | 140.8 |
| Ohio | 2295.4 | 111.2 | 133.1 |
| Eastern Great Lakes | 1459.7 | 112.0 | 120.3 |
| Tennessee-Cumberland | 535.9 | 185.7 | 196.1 |
| Southeast | 1099.6 | 140.1 | 162.0 |
| Western Great Lakes | 1811.3 | 131.4 | 136.9 |
| Upper Mississippi | 581.6 | 144.7 | 131.4 |
| Lower Mississippi | 744.6 | 175.6 | 179.0 |
| Missouri | 141.9 | 102.1 | 147.5 |
| Arkansas-White-Red | 184.6 | 114.0 | 105.0 |
| Western Gulf | 1899.1 | 135.8 | 185.0 |
| Colorado Basin | 18.3 | 261.4 | 256.6 |
| Great Basin | 26.8 | 116.5 | 179.7 |
| California | 314.1 | 110.6 | 154.4 |
| Pacific Northwest | 532.5 | 119.4 | 159.4 |
| National[1] | 14150.4 | 124.6 | 138.6 |

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[1] Excludes Hawaii and Alaska.

## TABLE 2

### INDUSTRIAL WASTEWATER DISCHARGE AND VALUE ADDED BY INDUSTRY GROUPS, 1959-68

| Industry | Total Industrial Wastewater Discharged, 1968 (Billions of Gal.) | 1968 Industrial Wastewater Discharge as a Percentage of 1959 Discharge | 1968 Value Added (Deflated) as a Percentage of 1959 Value Added |
|---|---|---|---|
| Food and Kindred Products | 752.8 | 131.9 | 130.3 |
| Textile Mill Products | 136.0 | 113.3 | 122.1 |
| Lumber | 92.7 | 73.8 | 99.9 |
| Paper | 2077.6 | 113.9 | 133.4 |
| Chemicals | 4175.1 | 136.4 | 181.9 |
| Petroleum and Coal | 1217.0 | 101.1 | 178.7 |
| Rubber | 128.4 | 107.9 | 137.8 |
| Leather | 14.9 | 125.0 | 143.2 |
| Stone, Clay, and Glass | 218.4 | 82.6 | 116.1 |
| Primary Metals | 4695.5 | 132.2 | 122.5 |
| Fabricated Metals | 65.0 | 158.5 | 148.7 |
| Machinery | 180.8 | 109.6 | 157.7 |
| Electrical Equipment | 118.4 | 134.5 | 242.3 |
| Transportation Equipment | 293.1 | 128.0 | 179.6 |

## TABLE 3

### REGIONAL INCIDENCE OF INDUSTRIAL WASTE DISCHARGE, BY MAJOR INDUSTRIAL SECTORS, 1968

PERCENT OF DISCHARGE OF INDUSTRY'S WASTEWATER, BY INDUSTRIAL WATER USE REGION

| | Regionally Assignable Discharge | New Eng. | Del. & Hud. | Chesa. Bay | East. Gr. Lak. St. Law. | Ohio Riv. | Tenn. Cum. | S.E. | West Gr. Lak. | Upper Miss. | Lower Miss. | Mo. | Ark. W&R | West. Gulf | Colo. Basin | Gr. Basin. | Cal.[1] | Pacf.[2] N.W. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Meat Products | 99.0 | .5 | 4.2 | 2.7 | 1.0 | 8.6 | 1.5 | 11.6 | 2.8 | 30.9 | 1.7 | 17.9 | 6.7 | 2.8 | D | D | 3.5 | 2.6 |
| Dairy Products | 98.8 | 7.5 | 4.3 | 4.9 | 8.9 | 5.1 | .6 | 2.3 | 12.5 | 24.7 | 2.8 | 4.3 | 4.7 | 1. | D | 1.3 | 7.0 | 6.4 |
| Canned & Frozen Foods | 93.1 | 1.4 | 3.2 | 2.5 | 3.9 | 2.3 | D | 29.0 | 5.3 | 2.9 | 1.9 | .9 | 1.8 | .8 | D | D | 20.5 | 16.7 |
| All Other Food Products | 84.4 | 3.7 | 5.9 | .7 | 1.0 | 4.0 | .2 | 3.4 | 9.8 | 14.0 | 11.7 | 6.7 | .3 | 1.5 | D | D | 20.3 | 1.2 |
| Textile Mill Products | 98.5 | 13.5 | 4.7 | 2.9 | .5 | 2.4 | 6.3 | 65.7 | D | .5 | 1.4 | -- | D | D | D | D | .6 | D |
| Paper & Allied Products | 98.7 | 11.9 | 3.3 | 4.9 | 3.2 | 2.4 | 3.1 | 28.9 | 7.8 | 6.0 | 2.7 | 1.0 | 3.8 | 2.5 | .1 | D | 2.1 | 15.0 |
| Chemical & Allied Products | 99.0 | 1.2 | 7.3 | 5.7 | 6.4 | 16.6 | 9.3 | 4.7 | 2.7 | 2.1 | 8.0 | .4 | .9 | 31.5 | D | D | .6 | 1.6 |
| Petroleum and Coal | 92.0 | .1 | 26.4 | D | 5.8 | 2.3 | -- | 2.0 | 13.0 | 1.2 | 10.2 | 1.6 | 1.1 | 27.5 | D | .1 | 8.4 | .2 |
| Rubber & Plastic, n.e.c. | 92.9 | 15.8 | 7.4 | 2.5 | 35.7 | 6.8 | D | 6.9 | 8.4 | 4.3 | 3.3 | D | .9 | D | D | D | .9 | D |
| Primary Metals | 96.6 | .7 | 6.1 | 6.9 | 17.5 | 29.4 | .5 | 1.7 | 25.2 | 2.6 | D | .4 | .6 | 3.4 | .2 | D | .2 | 1.2 |
| Machinery exc. Electrical | 99.9 | 14.9 | 34.0 | 1.2 | 4.8 | 9.0 | .8 | .7 | 12.5 | 19.8 | .3 | .2 | .3 | .7 | D | D | .7 | D |
| Electrical Machinery | 96.9 | 9.6 | 18. | 10.8 | 8.5 | 25.6 | 1.0 | 4.1 | 9.0 | 5. | .5 | .8 | .9 | D | D | D | 3.0 | D |
| Transportation Equipment | 97.0 | 31.4 | 3. | 5.1 | 33.3 | 4.6 | .6 | 1.7 | 7.1 | 2.1 | D | D | .5 | 5.0 | D | D | 2.2 | D |
| Assignable Discharge | 96.5 | 93.2 | 96.7 | 82.6 | 95.9 | 98.1 | 91.5 | 97.8 | 96.1 | 88.7 | 78.7 | 81.3 | 95.7 | 99.3 | 61.7 | 8.2 | 81.6 | 87.6 |
| Percent of Industrial Discharge, 1968 | 100.0 | 3,9 | 8.3 | 5.3 | 10.2 | 16.1 | 3.8 | 7.7 | 12.7 | 4.1 | 5.2 | 1.0 | 1.3 | 13.3 | 0.1 | 0.2 | 2.8 | 4.0 |
| Percent of Industrial Discharge, 1959 | 100.0 | 4.3 | 10.7 | 5.0 | 11.5 | 18.1 | 2.5 | 6.9 | 12.1 | 3.5 | 3.7 | 1.2 | 1.4 | 12.3 | 0.1 | 0.2 | 2.5 | 3.9 |

D = Disclosure not available due to disclosure constraints on U. S. Bureau of Census

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[1] Includes Hawaii

[2] Includes Alaska

## TABLE 4

### SOURCES OF INDUSTRIAL WASTE DISCHARGE, BY MAJOR INDUSTRIAL SECTORS, 1968

### PERCENT OF REGIONAL DISCHARGE BY INDUSTRY

| | New Eng. | Del. | Chesa Bay | East Gr. Lak. | Ohio Riv | Tenn. Cumb. | S.E. | West. Gr. Lak. | Upper Miss. | Low Miss. | Mo. | Ark. W&R | West. Gulf | Colo. Basin | Gr. Bas. | Cal. | Pacf. N.W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Meat Products | .1 | .4 | .4 | .1 | .4 | .3 | 1.0 | .2 | 5.3 | .2 | 12.5 | 3.6 | .1 | D | D | 1.1 | .5 |
| Dairy Products | .7 | .2 | .3 | .3 | .1 | - | .1 | .4 | 2.3 | .2 | 1.6 | 1.4 | - | D | 2.6 | 1.2 | .6 |
| Canned & Frozen Foods | .3 | .6 | .4 | .3 | .1 | - | 3.2 | .4 | .6 | .3 | .8 | 1.2 | - | D | D | 7.8 | 3.8 |
| All Other Food Products | 2.5 | 4.0 | .5 | .3 | .8 | .2 | 1.5 | 2.4 | 11.6 | 7.6 | 22.6 | .7 | .4 | D | D | 9.1 | 1.1 |
| Textile Mill Products | 3.3 | .5 | .5 | - | .1 | 1.6 | 8.1 | D | .1 | .3 | - | D | D | - | - | .3 | D |
| Paper & Allied Products | 44.1 | 5.8 | 13.4 | 4.5 | 2.1 | 11.8 | 54.6 | 9.0 | 21.4 | 7.7 | 14.3 | 42.7 | 2.7 | D | - | 14.1 | 58.5 |
| Chemical & Allied Products | 9.3 | 25.7 | 31.7 | 18.4 | 30.2 | 72.6 | 18.0 | 6.2 | 15.0 | 45.0 | 12.3 | 20.9 | 69.2 | 15.3 | D | 8.5 | 12.3 |
| Petroleum and Coal | .1 | 26.9 | D | 4.8 | 1.2 | - | 2.3 | 8.7 | 2.5 | 16.6 | 13.6 | 7.4 | 17.6 | D | 5.6 | 32.4 | .5 |
| Rubber & Plastic, n.e.c. | 3.6 | .8 | .4 | 3.1 | .4 | - | .8 | .6 | .9 | .6 | D | .6 | D | - | D | .4 | D |
| Primary Metals | 5.9 | 24.0 | 31.0 | 56.1 | 60.1 | 4.1 | 7.2 | 65.3 | 20.7 | D | 14.0 | 15.5 | 8.4 | 46.4 | D | 3.2 | 10.3 |
| Machinery exc. Electrical | 4.8 | 5.2 | .3 | .6 | .7 | .3 | .1 | 1.2 | 6.2 | .1 | .3 | .3 | .1 | D | D | .4 | D |
| Electrical Machinery | 2.0 | 1.8 | 1.7 | .7 | 1.3 | .2 | .4 | .6 | 1.0 | .1 | .6 | .6 | D | D | D | 1.1 | D |
| Transportation Equipment | 16.5 | .8 | 2.0 | 6.7 | .6 | .4 | .5 | 1.1 | 1.1 | D | D | .8 | .8 | D | D | 2.0 | D |
| Assignable Discharge | 93.2 | 96.7 | 82.6 | 95.9 | 98.1 | 91.5 | 97.8 | 96.1 | 88.7 | 78.7 | 81.3 | 95.7 | 99.9 | 61.7 | 8. | 81.6 | 87.6 |

With the exception of the petroleum industry in the Delaware-Hudson and California regions, paper, chemicals, and primary metals are the principal sources of industrial discharges. Clearly, these industries in the industrialized areas create the largest demand for curtailment of waste discharges.

## Industrial Waste Treatment, 1959-1968

Although industrial wastewater discharge has not grown as rapidly as industrial production--and the gap between the two rates of growth has widened[4]--the volume of industrial waste discharge must still be handled to attain, or maintain, acceptable levels of water quality. Four broad methods of curtailing the polluting effects of industrial liquid-borne wastes can be distinguished; (1) Waste treatment facilities can be added prior to discharge; (2) A plant can also discharge its wastes to a sewer and thereby place the responsibility for treatment upon a political jurisdiction; (3) Application to land, either through surface irrigation or well injection, can be a very thorough treatment technique, provided that precautions to prevent ground water contamination or run-off of pollutants are exercised; (4) Process change is, from both an environmental and administrative standpoint, perhaps the most attractive technique because of its reliability, predictability, and potential for recycling of waste materials. Process change, though, is part of the economics of water use generally. Accordingly, a discussion of process change is deferred to a later chapter which concerns water as an industrial input.

Superficial inspection of Tables 5 and 6 suggests that progress in the treatment of wastes by industry has been made during the last decade. In 1968, over 30 percent of industrial wastewater was reported to have received some kind of treatment performed by industry. This represents an increase of about 87 percent in treated discharge since 1959. In all regions and for most industries, the amount of wastewater treatment performed by manufacturers increased both absolutely and relative to total discharge over the period. Based on a consideration of the development of water quality standards, greater regulatory activity and other developments discussed in the previous section, these findings might be expected. It cannot, however, be inferred from these data that the amount of industrial pollutants reaching water has necessarily decreased.

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[4] Excluding Alaska and Hawaii, between 1959 and 1964 value added (in constant dollars) grew at an annual rate of 2.2 percent and industrial discharge grew at a rate of 2.7 percent; but between 1964 and 1968 value added grew at a rate of 4.8 percent which exceeds the 2.1 percent rate of growth of discharge by a wide enough margin to give the entire decade a creditable showing with respect to water productivity in manufacturing.

## TABLE 5

## PERCENTAGE OF INDUSTRIAL WASTEWATER RECEIVING TREATMENT AND GROWTH IN TREATMENT BY INDUSTRIAL WATER USE REGIONS, 1959-68

| Water Use Region | Industrial Wastewater Discharge | | | | Annual Rate of Growth of Treated Discharge | |
|---|---|---|---|---|---|---|
| | Percent Treated | | | | | |
| | 1959[1] | 1964[2] | 1968 | 1959-68 | 1959-64 | 1964-68 |
| New England | 4.7 | 11.4 | 10.0 | 10.4 | 19.1 | .4 |
| Delaware-Hudson | 25.0 | 40.2 | 42.0 | 5.7 | 9.6 | .8 |
| Chesapeake Bay | 24.5 | 25.6 | 28.5 | 5.1 | 5.8 | 4.1 |
| Ohio | 14.5 | 17.7 | 23.3 | 6.6 | 6.7 | 6.5 |
| Eastern Great Lakes | 20.3 | 31.7 | 22.0 | 2.2 | 11.6 | -8.3 |
| Tennessee-Cumberland | 18.0 | 31.3 | 26.4 | 11.8 | 19.6 | 2.9 |
| Southeast | 17.3 | 36.8 | 43.1 | 14.9 | 19.3 | 9.6 |
| Western Great Lakes | 19.4 | 34.8 | 41.7 | 12.2 | 15.3 | 8.5 |
| Upper Mississippi | 16.9 | 35.0 | 23.7 | 8.2 | 21.0 | -5.5 |
| Lower Mississippi | 6.4 | 23.8 | 21.0 | 21.6 | 38.0 | 2.9 |
| Missouri | 16.5 | 48.1 | 45.5 | 12.2 | 22.0 | 1.0 |
| Arkansas-White-Red | 30.9 | 50.6 | 67.0 | 10.6 | 15.2 | 8.9 |
| Western Gulf | 31.3 | 22.6 | 23.2 | .1 | -2.6 | 3.5 |
| Colorado Basin | 14.3 | 31.3 | 19.1 | 14.9 | 38.0 | -8.5 |
| Great Basin | 13.0 | 58.6 | 42.9 | 16.1 | 41.0 | -9.3 |
| California | 51.8 | 59.7 | 55.4 | 1.9 | 5.3 | -2.2 |
| Pacific Northwest | 14.3 | 29.6 | 36.3 | 13.1 | 20.0 | 4.8 |
| National[3] | 20.3 | 29.2 | 30.4 | 7.2 | 10.5 | 3.1 |

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[1] Volume of treated discharge derived from 1958 Census of Manufacturers.

[2] Volume of treated discharge derived from 1963 Census of Manufacturers.

[3] Excludes Alaska and Hawaii.

## TABLE 6

### PERCENTAGE OF INDUSTRIAL WASTEWATER RECEIVING TREATMENT AND GROWTH IN TREATMENT BY INDUSTRY GROUPS, 1959-68

| Industry Group | Percent of Industrial Wastewater Discharge Treated | | | Annual Rate of Growth of Treated Discharge | | |
|---|---|---|---|---|---|---|
| | 1959 | 1964 | 1968 | 1959-68 | 1959-64 | 1964-68 |
| Food and Kindred Products | 13.0 | 22.9 | 24.6 | 10.7 | 16.4 | 4.0 |
| Textile Mill Products | 14.2 | 25.9 | 39.7 | 13.7 | 15.5 | 11.5 |
| Lumber | 24.6 | 27.6 | 20.4 | -5.3 | 1.9 | -13.5 |
| Paper | 41.8 | 36.4 | 44.0 | 2.1 | -1 | 6.7 |
| Chemicals | 16.3 | 16.0 | 16.1 | 3.4 | 3.4 | 3.4 |
| Petroleum and Coal | 54.5 | 76.4 | 75.4 | 3.8 | 8.9 | -1.8 |
| Rubber | 3.4 | 7.8 | 5.4 | 6.4 | 17.6 | -6.3 |
| Leather | 16.7 | 63.6 | 66.7 | 19.6 | 28.5 | 9.3 |
| Stone, Clay and Glass | 4.2 | 18.8 | 16.5 | 14.1 | 30.0 | -3.2 |
| Primary Metals | 15.1 | 26.9 | 30.8 | 11.5 | 16.7 | 5.4 |
| Fabricated Metals | 7.3 | 12.0 | 13.8 | 13.0 | 14.9 | 10.7 |
| Machinery | 18.8 | 8.0 | 13.8 | -2.3 | -17.4 | 20.0 |
| Electrical Equipment | 8.0 | 17.0 | 23.7 | 16.7 | 16.5 | 16.9 |
| Transportation Equipment | 9.6 | 10.3 | 7.8 | .5 | 1.8 | -1.1 |

Available data do not permit estimation of the degree of treatment received by final industrial waste discharge. In the absence of inventories of industrial treatment facilities analagous to the Municipal Waste Inventories, it is presently impossible to estimate the amount and rate of change of the discharge of industrial liquid-borne pollutants.

Another reason that the apparent increases in wastewater treatment by industry do not necessarily imply a decrease in industrial pollutants is that treatment of industrial wastewater is often a requirement for discharge to sewers. As presented in the 1968 Water Use in Manufacturing, the data did not allow an estimate of treatment prior to sewer discharge or application to land. In 1964 the volume of industrial waste receiving treatment prior to discharge to sewers or ground appears to have been about 5 percent of the total treated discharge. This percentage may have increased by 1968 because of the growth in municipal waste treatment and associated pretreatment requirements for industrial connections.

One disturbing finding which emerges from an examination of the data over the period 1959 to 1968 is that treatment of wastes by industry grew at a considerably faster rate from 1959 to 1964 (10.5 percent annual rate) than from 1964 to 1968 (only a 3.1 percent annual rate, cf. Table 5). In fact, in five of the seventeen water use regions and five of the fourteen industries there was both a relative and absolute decline in the amount of industrial wastewater receiving some kind of treatment over the period 1964-1968. As a consequence of the differing rates of growth in treatment, the amount of untreated wastewater discharged by industry grew at an annual rate of 1.6 percent over the 1964-1968 period, even though total discharge of industrial wastewater grew at a slower rate in the later period (2.1 percent annual rate of growth) than in the earlier period (2.8 percent). The nature and detail of available data do not permit an investigation as to the many possible reasons for the decline in the rate of growth of industrial wastewater treatment. However, the period 1964-1968 experienced generally increasing rates of interest which, because the rate of interest is an integral part of the cost of capital investments to industry, may have discouraged or postponed investment generally and investment for industrial treatment facilities in particular. Another conjecture which might bear on the decline in the rate of growth of industrial treatment concerns the responses of firms to increased scarcity of fresh water for industrial use and increased regulatory pressures. More stringent effluent requirements and increased enforcement of such requirements provide an incentive to industry to amend production processes to curtail the production of liquid-borne pollutants and/or to find profitable uses for the would-be waste discharges. Also, while regulatory constraints on industrial discharges have become tighter, the demand on available water supplies has increased, which provides an incentive to economize on water intake and discharge. The total effect of these pressures may have been to drive below the 20 million-gallons-a-year threshold some of the establishments which had reported in the Water Use in Manufacturing series prior to 1968. Thus, these establishments did not report in the 1968 survey. In other words, establishments which significantly altered processes to decrease the amount of their discharge to be treated may have thereby eliminated themselves from the request to report their discharges and associated amount of treatment to the Bureau of the Census, and decreased the apparent rate of growth in industrial wastewater treatment.

It should also be noted that quantitative representations of wastewater treated over time may not be an accurate indication of growth. Industrial management's view of what constitutes treatment is unconstrained by definition, so that waste-amending practices tend in all cases to be reported as treatment. But as waste treatment requirements become more stringent, intake economies and segregation modify utilization practices in such fashion that the amount of wastewater treated declines in rough proportion to the intensity of treatment. (For example--a factory in which water application is divided equally among cooling, process, and sanitary purposes might have discharged in 1959 through a common outfall, with coarse screening the only treatment provided, and have reported treatment of 100 percent of its aqueous wastes; by 1968, as a result of regulatory pressures, the same factory might be discharging sanitary wastes to a public sewer, discharging once through cooling waters through a separate outfall to prevent contamination by other wastewaters and providing a high degree of treatment to process wastes, yet report--quite accurately--that only 33 percent of its wastes were treated.) To what extent such considerations are reflected in the apparent slowing of waste treatment growth we cannot guess.

## Public Treatment of Industrial Wastes

Discharge of industrial wastewater to public sewers places the requirement for adequate waste treatment upon local public agencies responsible for municipal waste treatment. As wastewater treatment at the secondary level (i.e., about 80 to 90 percent BOD reduction) or above becomes more prevalent among municipalities, the degree of treatment of sewered industrial wastewater should generally increase. However, as municipalities raise their target rates of waste removal, they must become more discriminating about the types and timing of industrial discharges that they will accept in order to prevent adverse consequences on the operation of their treatment works. Increased selectivity of acceptable discharge to sewers generally means outright prohibition on the discharges of certain industrial residuals and/or pretreatment requirements. For the sewered manufacturing plant, greater selectivity can translate into separation of waste streams and/or treatment of discharges bound for the sewer, both of which entail an increase in costs. From the data reported in the Water Use in Manufacturing series it appears that these developments have been an offset to the subsidies provided by Federal and State grants for municipal wastewater treatment plant construction.

From 1959 to 1968 the percentage of industrial wastewater discharged to sewers declined from 8.7 percent to 7.2 percent (cf. Table 7). However, all of this decline took place in the 1959-1964 period, and over the 1964-1968 span relative discharge to sewers remained virtually constant, with the absolute amount of sewered discharge increasing slightly. Although the relative amount of industrial discharge going to sewers is rather small, it can be inferred from Table 8 that municipal waste treatment is the primary method of curtailing industrial liquid-borne pollutants from the food processing, textiles, rubber, leather, and the various metal manufacturing industries.

(The percentages in Table 8 probably understate the relative amount of industrial discharge going to sewers by a percentage point because municipal waste treatment is also the primary method by which the water-borne wastes of minor urban manufacturing establishments whose intake is less than 20 million gallons a year are handled.)

## Ground Disposal of Industrial Wastes

Discharge to the ground can be an effective method of treating industrial wastewater. Direct application to land utilizes the evaporative powers of the atmosphere and the filtering action of soil and rock strata to eliminate and purify industrial wastewater. Deep-well injection is a method of withholding and isolating particularly dangerous or conservative industrial wastes from surface streams. The use of disposal to land as a technique is constrained by the cost and availability of land, the possible contamination of ground waters, and the possible nuisances of noxious odors and aesthetic degradation. However, as long as proper precautions are taken, applications to land are valuable in cleansing and recycling liquid industrial discharge.

Discharge of industrial wastewater to the ground is not a prevalent disposal technique; according to the data presented in the Water Use in Manufacturing, 1968 only 1.3 percent of industrial wastewater was discharged to the ground (cf. Table 9). The use of land as a disposal medium has grown however, between 1959 and 1968 industrial discharges going to the ground grew at an annual rate of 7.8 percent. From Table 9 it appears that ground discharge is a significant technique of disposal in the sparsely populated and arid regions of the Colorado Basin and Great Basin, where the wastes may have an economic value for irrigation use. Ground discharge is generally least used in the humid and often densely populated areas east of the Mississippi River and in the Western Gulf. Among industries, the food and kindred industry group discharged the largest percentage of its wastewater to the ground--5.8 percent in 1968 (cf. Table 10) -- and the chemicals and primary metals groups discharged to the ground 40.3 billion gallons and 38.1 billion gallons, respectively.

## TABLE 7

### PERCENTAGE OF INDUSTRIAL WASTEWATER DISCHARGED TO SEWERS AND GROWTH OF SEWERED DISCHARGE BY INDUSTRIAL WATER USE REGION, 1959-68

| | Industrial Wastewater Discharge Percent Discharged to Sewers | | | Annual Rate of Growth of Sewered Discharge | | |
|---|---|---|---|---|---|---|
| Water Use Region | 1959 | 1964 | 1968 | 1959-1968 | 1959-1964 | 1964-1968 |
| New England | 12.6 | 10.0 | 8.4 | -3.0 | -5.0 | -.5 |
| Delaware-Hudson | 7.4 | 4.0 | 7.3 | - .4 | -11.8 | 16.1 |
| Chesapeake Bay | 5.0 | 5.6 | 4.3 | 1.7 | 7.4 | -5.1 |
| Ohio | 5.4 | 7.1 | 7.5 | 4.9 | 8.2 | .8 |
| Eastern Great Lakes | 10.1 | 10.7 | 13.9 | 4.9 | 3.1 | 7.1 |
| Tennessee-Cumberland | 3.5 | 2.7 | 2.6 | 3.7 | 1.9 | 6.0 |
| Southeast | 5.0 | 5.4 | 5.2 | 4.3 | 4.3 | 4.3 |
| Western Great Lakes | 17.7 | 9.8 | 7.4 | -6.5 | -8.9 | -3.3 |
| Upper Mississippi | 26.4 | 21.1 | 18.5 | .2 | - .4 | .9 |
| Lower Mississippi | 6.4 | 3.5 | 3.1 | -1.9 | -5.8 | 3.2 |
| Missouri | 20.1 | 27.9 | 17.8 | -1.2 | 5.1 | -8.5 |
| Arkansas-White-Red | 4.9 | 8.0 | 7.9 | 6.8 | 11.8 | .7 |
| Western Gulf | .9 | .8 | .8 | 1.7 | 1.5 | 2.1 |
| Colorado Basin | 42.9 | 25.0 | 20.2 | 2.4 | 5.9 | -2.0 |
| Great Basin | 4.4 | 6.9 | 6.3 | 6.1 | 14.9 | -4.0 |
| California | 15.1 | 15.1 | 16.8 | 2.3 | 2.2 | 2.5 |
| Pacific Northwest | 9.6 | 6.7 | 5.7 | -3.8 | -3.5 | -4.5 |
| National[1] | 8.7 | 7.3 | 7.2 | .3 | - .9 | 1.9 |

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[1] Excludes Alaska and Hawaii.

## TABLE 8

## PERCENTAGE OF INDUSTRIAL WASTEWATER DISCHARGED TO SEWERS AND GROWTH OF SEWERED DISCHARGE BY INDUSTRY GROUPS, 1959-68

| | Industrial Wastewater Discharge Percent Discharged to Sewers | | | Annual Rate of Growth of Sewered Discharge | | |
|---|---|---|---|---|---|---|
| Industry Group | 1959 | 1964 | 1968 | 1959-1968 | 1959-1964 | 1964-1968 |
| Food and Kindred Products | 36.6 | 35.0 | 31.6 | 1.4 | 2.9 | - .3 |
| Textile Mill Products | 31.7 | 32.6 | 37.2 | 3.2 | 3.0 | 3.6 |
| Lumber | 6.3 | 3.3 | 2.7 | -12.1 | -13.0 | -11.1 |
| Paper | 4.4 | 4.2 | 3.5 | - 1.2 | 0 | - 2.7 |
| Chemicals | 3.5 | 4.2 | 4.3 | 6.0 | 7.4 | 4.3 |
| Petroleum and Coal | .9 | 2.4 | .6 | - 4.1 | 23.0 | -43.0 |
| Rubber | 19.3 | 15.5 | 17.4 | - .3 | .9 | - 1.7 |
| Leather | 50.0 | 63.6 | 68.0 | 6.1 | 3.1 | 9.9 |
| Stone, Clay and Glass | 8.0 | 8.7 | 9.4 | - .3 | - 2.0 | 1.8 |
| Primary Metals | 7.4 | 3.6 | 3.1 | - 6.5 | - 9.8 | - 2.2 |
| Fabricated Metals | 70.7 | 64.0 | 59.4 | 3.2 | 2.0 | 4.8 |
| Machinery | 22.4 | 26.8 | 24.6 | 2.1 | 1.6 | 2.7 |
| Electrical Equipment | 46.6 | 53.8 | 62.8 | 6.8 | 3.6 | 11.0 |
| Transportation Equipment | 36.2 | 33.3 | 26.3 | - .8 | - 1.0 | - .6 |

## TABLE 9

### PERCENTAGE OF INDUSTRIAL WASTEWATER DISCHARGED TO THE GROUND AND GROWTH OF GROUND DISCHARGE BY INDUSTRIAL WATER USE REGIONS, 1959-68

| | Industrial Wastewater Discharge Percent Discharged to Ground | | | Annual Rate of Growth of Discharge to Ground | | |
|---|---|---|---|---|---|---|
| Water Use Region | 1959 | 1964 | 1968 | 1959-1968 | 1959-1964 | 1964-1968 |
| New England | .4 | .4 | .9 | 10.9 | 0 | 26.0 |
| Delaware-Hudson | 1.1 | 1.3 | 1.5 | 3.7 | 4.2 | 3.0 |
| Chesapeake Bay | 1.2 | 1.5 | .6 | 1.7 | 7.4 | - 5.0 |
| Ohio | .6 | .6 | .5 | - .3 | 2.9 | - 4.5 |
| Eastern Great Lakes | .6 | .6 | .5 | - 1.8 | 2.4 | - 6.8 |
| Tennessee-Cumberland | .4 | 2.5 | .3 | 6.8 | N.C[2] | N.C[2] |
| Southeast | .9 | 1.3 | 1.7 | 11.3 | 11.4 | 11.3 |
| Western Great Lakes | .4 | .5 | .6 | 6.6 | 5.9 | 7.5 |
| Upper Mississippi | 1.7 | 1.2 | 4.3 | 15.1 | - 3.0 | 43.0 |
| Lower Mississippi | .2 | .5 | 1.5 | 35.0 | 25.0 | 39.0 |
| Missouri | .7 | 1.6 | 1.4 | 8.0 | 14.9 | 0 |
| Arkansas-White-Red | 1.2 | 1.7 | 2.8 | 11.2 | 8.4 | 14.7 |
| Western Gulf | .2 | .1 | .5 | 13.0 | - 7.8 | N.C[2] |
| Colorado-Basin | 28.6 | 6.3 | 44.3 | 16.8 | -12.9 | N.C[2] |
| Great Basin | N.R[3] | 6.9 | 21.3 | N.R[3] | N.R[3] | 30.0 |
| California | 4.6 | 6.0 | 6.1 | 4.3 | 7.9 | 0 |
| Pacific Northwest | 2.2 | 3.7 | 4.1 | 10.8 | 14.9 | 5.9 |
| National[1] | .8 | 1.1 | 1.3 | 7.8 | 7.7 | 7.9 |

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[1] Excludes Alaska and Hawaii.

[2] Exceeds 50 percent in absolute value.

[3] Calculation not possible because the necessary datum was not reported.

## TABLE 10

## PERCENTAGE OF INDUSTRIAL WASTEWATER DISCHARGED TO THE GROUND AND GROWTH OF GROUND DISCHARGE BY INDUSTRY GROUPS, 1959-68

| | Industrial Waste Discharge Percent Discharged to Ground | | | Annual Rate of Growth of Discharge to Ground | | |
|---|---|---|---|---|---|---|
| Industry Group | 1959 | 1964 | 1968 | 1959-1968 | 1959-1964 | 1964-1968 |
| Food and Kindred Products | 4.2 | 11.5 | 5.8 | 6.8 | 27.0 | -13.9 |
| Textile Mill Products | 1.7 | 3.7 | 1.0 | -3.9 | 20.0 | -27.3 |
| Lumber | 1.6 | 2.4 | 4.1 | 7.4 | 8.4 | 6.1 |
| Paper | .5 | .6 | .8 | 6.5 | 4.1 | 9.7 |
| Chemicals | .6 | 1.0 | 1.0 | 8.7 | 14.9 | 1.5 |
| Petroleum and Coal | .4 | .4 | 1.1 | 11.5 | 0 | 28.0 |
| Rubber | 1.7 | 1.7 | 2.0 | 2.5 | 0 | 5.7 |
| Leather | 8.3 | 0 | 2.7 | -9.7 | -- | -- |
| Stone, Clay and Glass | 1.9 | 8.3 | 5.3 | 9.8 | 29.0 | -10.4 |
| Primary Metals | .6 | 1.3 | .9 | 5.4 | 14.9 | - 5.4 |
| Electrical Equipment | 1.1 | 3.4 | 3.3 | 14.9 | 24.6 | 6.1 |
| Transportation Equipment | 1.7 | 2.1 | 2.5 | 6.9 | 4.6 | 9.9 |

# II

# PROCESS AND THE USE OF WATER IN INDUSTRY

## Introduction

The chapter considers the utility of water as an industrial raw material, the increasing intensity of its application, the substitution of capital for water inputs, and the relationship of these phenomena to water quality and effluent treatment.

## Summation

The real price of water--measured by its scarcity and the cost of its application--is increasing for industry. In consequence, manufacturers are using it with growing intensity. Use of capital to provide more effective utilization of each intake unit at each application and to increase the number of applications by recycling is indicated by positive correlations between growth of output per intake gallon with (a) growth of output, and (b) water scarcity. Neither characteristic correlates with growth of industrial waste treatment, suggesting that management response to an increase in the price of water is limited to each firm's internal operations and does not extend to measures that will reduce prices for society as a whole. Nevertheless, increased demand for water leads to processing methods that result in reduced dependence on the available supply, thus supplementing--and in some degree substituting for--the effect of waste treatment.

# PROCESS CHANGE AND THE USE OF WATER IN INDUSTRY

## Utility of Water in Manufacturing

In 1968 about 15.5 trillion gallons of water were withdrawn in the United States by manufacturers (cf. Table 11)--an increase of 27.5 percent from 1959. According to U.S. Geological Survey sources, industry, exclusive of electrical utilities, accounted for 14.5 percent of withdrawals in the United States from 1950 to 1965. Water provides a number of productive services within manufacturing processes. A number of products, notably beverages and prepared foods, incorporate water directly into the product. Water can be used to transport materials in a manufacturing process; for example, water is used to carry partially prepared fruits and vegetables between stages of production. But the most common use of water by industry is to transport or flush away residual matter, the inevitable by-products of manufacturing processes that must be carried away in order to prevent counter-productive effects.

Much of the intake of water by industry is directly toward cooling; in 1968, the percentage of initial intake for the purpose of cooling amounted to 65.5 percent (cf. Table 12). Cooling water is used to absorb the heat arising from the difference between thermal energy generated and that used in production. The heat, in turn, can be identified as a residual from industrial production. Although cooling tends to be the major use of water in industry, process water carried almost all residuals other than heat. Respondents in the Conference Board survey indicated that 93.4 percent of the BOD, 89 percent of chemical oxygen demand (COD), and 85 percent of suspended solids contained in their wastewater were contributed directly by the production process. Table 12 indicates waste concentrations in process water, generally highest for paper and allied products. Clearly, it is the use of water directly in the production process which creates a need for curtailment of the amount of residuals discharged to waterways.

## Process Change--An Alternative to Treatment

The trends presented in the previous chapter indicated that wastewater treatment by industry has increased over the past decade, but that considerable increases in the amound and, probably, the degree of wastewater treatment are necessary in order to meet current regulatory standards for waterways. An alternative to end-of-stream treatment as a method for reducing the discharge of liquid-borne residuals is alteration of production processes so thatthe production of residuals decreases. Process change can involve adoption of known low-residual techniques, development of new techniques, alteration of product lines from high-residual to low-residual goods, and use of low-residual raw materials.

## TABLE 11

### VOLUME OF INTAKE AND PERCENT CONSUMED BY INDUSTRY GROUPS, 1968

| Industry | Intake, 1968 (Billions of Gallons) | Percent Consumed, 1968 |
|---|---|---|
| Food and Kindred Products | 811 | 7.2 |
| Textile Mill Products | 154 | 11.7 |
| Lumber | 118 | 21.2 |
| Paper | 2252 | 7.7 |
| Chemicals | 4476 | 6.7 |
| Petroleum and Coal | 1435 | 15.2 |
| Rubber | 135 | 5.2 |
| Leather | 16 | 6.3 |
| Stone, Clay, and Glass | 251 | 13.1 |
| Primary Metals | 5005 | 6.2 |
| Fabricated Metals | 68 | 4.4 |
| Machinery | 189 | 4.2 |
| Electrical Equipment | 127 | 7.1 |
| Transportation Equipment | 313 | 6.4 |
| All Manufacturing | 15467 | 9.6 |

# TABLE 12

## COMPOSITION OF INDUSTRIAL WATER INTAKE AND WASTE CONCENTRATION BY INDUSTRY GROUPS 1968

| Industry | PERCENT OF INTAKE, 1968 | | | WASTE CONCENTRATION OF PROCESS WATER (in p.p.m.)[1] | | |
|---|---|---|---|---|---|---|
| | Cooling | Process | Other | BOD | COD | SS |
| Food and Kindred Products | 52.6 | 35.8 | 11.6 | 87 | 114 | 703 |
| Textile Mill Products | 15.3 | 70.7 | 14.0 | 304 | 327 | 70 |
| Paper | 28.9 | 65.6 | 5.5 | 336 | 3565 | 388 |
| Chemicals | 78.9 | 16.4 | 4.7 | 130 | 378 | 225 |
| Petroleum and Coal | 85.7 | 6.6 | 7.7 | 52 | 210 | 76 |
| Rubber | 70.9 | 17.6 | 11.5 | 17 | 57 | 30 |
| Primary Metals | 72.6 | 24.1 | 3.3 | 18 | 80 | 259 |
| Fabricated Metals | 28.4 | 54.8 | 16.8 | N.A.[2] | N.A. | N.A. |
| Machinery | 72.0 | 15.3 | 12.7 | N.A. | N.A. | N.A. |
| Electrical Equipment | 38.4 | 36.8 | 24.8 | N.A. | N.A. | N.A. |
| Transportation Equipment | 25.6 | 20.2 | 54.2 | N.A. | N.A. | N.A. |
| All Manufacturing | 65.5 | 27.8 | 6.7 | N.A. | N.A. | N.A. |

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[1] Source: Conference Board Survey of 800 manufacturing establishments.

[2] N.A.--not available.

Most of the documented cases of process changes which reduced the pollutant loadings per unit of product indicate that the reduction in wastes produced was fortuitous rather than deliberate. For example, in the pulp and paper industry the substitution of the sulfate process for the older and much more residual-intensive sulfite process has occurred primarily because the newer process effects lower unit costs of production than the older process. The consequent decrease in residuals production has been, from the point of view of the pulp producer, an incidental benefit.

One piece of evidence suggests that firms are directing investments toward process change in order to reduce waste loadings. The survey on water pollution abatement costs conducted by the Conference Board[1] indicates that 27.9 percent of capital expenditures for water pollution control by the sampled plants were for manufacturing changes to reduce water pollution. This percentage varied from 35.6 percent in paper and allied products to 2.8 percent in textile mill products.

Lack of data prevents an analysis and evaluation of the extent and changes over time in alterations of production process that reduce the amount of residuals generated. Only a few case studies of process change exist, and these have generally examined plants in which a dramatic change in production technique was instituted. Most process changes, like technological progress in industry generally, tend to be incremental and cumulative. No systematic and inclusive collection of data related to process change over time (for example, investment for process change and waste loads produced) has ever been undertaken, and, thus, direct assessment of the rate of process change and its effects on waste loadings is not possible.

Indirect inferences concerning changes in the pollutant content of industry's discharged wastewater can be made by examining changes in the intake, use and discharge of water over time in industry. As stated in an earlier volume in this series of reports to the Congress, "there is an indication that reduction in volume of wastewater is often accompanied by a reduction in the volume of pollutants discharged. While concentrations of pollutants might, in the normal order of things, be expected to rise in direct proportion to the decline in the volume of carrying liquid, this is simply not the case for industry as a whole. The reason is that operating practices--"good housekeeping"--have a high degree of influence on the volume of wastes produced in a factory; and when hydraulic controls are tightened there is a corollary reduction in materials losses. In addition to this influence on waste volume, there are direct reductions attributable to engineering improvement specifically aimed at materials reclamation."[2] In other words, economizing on water intake, and thus discharge, is often accompanied by increased attention to the production and handling of water-borne residuals, and materials control generally, which have a negative effect on the amount of pollutants discharged.

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[1] U. S. Environmental Protection Agency, The Economics of Clean Water, Vol. III, January 1972.

In addition to having a generally depressing influence on the production of residuals, economizing on water intake will have beneficial effects for environmental enhancement and protection. Water not withdrawn for the purpose of residual elimination means more water is available in streams for assimilative processes. Recycling and reuse of water is a common method of economizing on water intake per unit of product. Recycling of water can cause an increase in the concentration of pollutants in industrial wastewater which generally lowers the cost of treatment per unit of waste and cheapens the cost of by-product recovery.

The trends in water intake for industrial water use regions and industry groups reported in Tables 13 and 14 indicate that water intake increased over time for all regions and for most industries. This finding is not surprising, given the growth in production in the economy over the period 1959-1968. However, growth in production alone hardly accounts for differences in the trends in water intake across regions and across industries; the percentages of variation in water intake growth explained by growth in value added are only 18 and 21 percent for regions and for industries, respectively, neither of which is different from zero by the usual tests of statistical significance. In other words, growth in water withdrawals by industry has not been primarily conditioned by growth in industrial production.

Examination of the ratio of growth in value added (in constant dollar) to growth in water intake (cf. Tables 13 and 14 ) indicates that production has generally grown more rapidly than water intake. Productivity, which is most often defined with respect to labor, can be defined as the ratio of the rate of growth of output to the input in question. The sources of productivity increases are improvements in the quality of the input, increased application or substitution of other inputs, and technological progress, by which is meant improvements in products and production processes. Although the treatment of wastewaters discharged to surface streams has increased in both volume and degree, it

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[2] U. S. Department of the Interior, Federal Water Pollution Control Administration, The Cost of Clean Water, Vol. II (U. S. Government Printing Office, 1968), p. 82

## TABLE 13

## TRENDS IN INDUSTRIAL WATER INTAKE AND IN MEASURES OF PROCESS CHANGE BY INDUSTRIAL WATER USE REGIONS, 1959-1968

| | 1968 as a Percentage of 1959 | | | | |
|---|---|---|---|---|---|
| | Intake | Value Added (Deflated)/Intake | Value Added (Deflated)/Use | Value Added (Deflated)/Discharge | Recycle Ratio,1968 |
| New England | 105.3 | 125.0 | 108.8 | 116.4 | 1.65 |
| Middle Atlantic[1] | 110.7 | 109.8 | 128.8 | 110.0 | 1.78 |
| Ohio | 114.3 | 116.4 | 105.1 | 119.7 | 1.68 |
| Eastern Great Lakes | 117.5 | 102.4 | 94.9 | 107.4 | 1.72 |
| Tennessee-Cumberland | 187.3 | 104.7 | 127.9 | 105.8 | 1.85 |
| Southeast | 138.4 | 117.1 | 97.6 | 115.7 | 3.15 |
| Western Great Lakes | 135.6 | 102.4 | 114.7 | 104.2 | 1.52 |
| Upper Mississippi | 157.6 | 83.4 | 83.8 | 90.8 | 2.18 |
| Lower Mississippi | 178.2 | 100.4 | 99.5 | 101.9 | 2.30 |
| Missouri | 108.2 | 136.3 | 121.6 | 144.5 | 3.56 |
| Arkansas-White-Red | 120.3 | 87.0 | 89.4 | 92.1 | 6.93 |
| Western Gulf | 136.4 | 136.2 | 117.7 | 136.8 | 3.49 |
| Colorado Basin | 122.6 | 209.3 | 227.5 | 98.2 | 6.15 |
| Great Basin | 113.9 | 157.8 | 118.5 | 154.2 | 5.50 |
| California | 113.5 | 136.0 | 121.7 | 139.6 | 4.09 |
| Pacific Northwest | 128.1 | 124.4 | 104.5 | 133.6 | 2.82 |
| National[2] | 126.9 | 109.2 | 103.5 | 111.2 | 2.31 |

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[1] Delaware-Hudson and Chesapeake Bay

[2] Excludes Alaska and Hawaii.

## TABLE 14

### TRENDS IN INDUSTRIAL WATER INTAKE AND IN MEASURES OF PROCESS CHANGE BY INDUSTRY GROUPS, 1959-68

| | 1968 as a Percentage of 1959 | | | | |
|---|---|---|---|---|---|
| | Intake | Value Added (Deflated)/Intake | Value Added (Delfated)/Use | Value Added (Deflated)/Discharge | Recycle Ratio,1968 |
| Food and Kindred Products | 130.0 | 100.2 | 125.6 | 98.8 | 1.66 |
| Textile Mill Products | 114.1 | 123.5 | 78.2 | 124.3 | 2.13 |
| Lumber | 84.3 | 118.5 | 89.7 | 135.3 | 1.74 |
| Paper | 116.3 | 106.8 | 115.1 | 109.0 | 2.90 |
| Chemicals | 138.1 | 122.0 | 93.5 | 123.5 | 2.10 |
| Petroleum and Coal | 108.8 | 163.1 | 140.8 | 175,6 | 5.08 |
| Rubber and Plastics | 106.3 | 129.6 | 111.7 | 128.1 | 1.99 |
| Leather | 133.3 | 107.4 | 100.2 | 114.6 | 1.25 |
| Stone, Clay and Glass | 100.0 | 116.1 | 115.9 | 116.9 | 1.64 |
| Primary Metals | 135.2 | 90.2 | 89.0 | 92.3 | 1.55 |
| Fabricated Metals | 154.5 | 96.2 | 62.4 | 93.8 | 2.48 |
| Machinery | 110.5 | 141.7 | 116.3 | 142.8 | 1.79 |
| Electrical Equipment | 136.6 | 159.4 | 93.6 | 162.4 | 2.91 |
| Transportation Equipment | 120.4 | 119.4 | 82.4 | 112.4 | 2.91 |

is unlikely that stream quality has increased to the point where less water per unit of product is needed. Instead, increased deterioration of surface waterbodies can lead to an increase in water productivity: decreased quality of intake can lead to increased treatment prior to application, which effectively raises the cost of utilizing an additional unit of water and provides an incentive to economize on intake. It would appear, then, that the increased productivity of water in industry is attributable to substitution of other inputs (primarily capital and less pollutional raw materials) and improvements in production technique.

Similarly, the ratio of the growth in value added (deflated) to the growth in industrial wastewater discharge generally increased over the 1959-1968 period. In fact, for most of the regions and industries this ratio grew at a slightly faster rate than did the ratio of value added to intake. (Water use is defined as the quantity of water that would have been required if no water were recirculated or reused, less consumption and evaporative loss.) Use measures the actual application of water in production processes. From Tables 13 and 14 no clear pattern emerges with respect to the growth of value added relative to use; increases and decreases in this ratio are almost ewually numerous across regions and industries although nationally there was a slight trend toward using less water per (constant) dollar of production.

Clearly, there has been a discernable, and appratently deliberate, effort by industry to economize on water intake. Additionally, casual inspection of the first and second columns of Tables 13 and 14 shows that there has been considerable variation between regions and industries with respect to trends in intake and productivity of intake. These trends are consistent with the proposition that water is not treated as a freely available commodity by industry. What, then, have been the incentives which have led industry to economize on water intake?

## Influences on Process Modification

One possibility is that incentives to economize on water use emanate from the price of water and product demand. To examine this possibility, the sixteen industrial water use regions were cross-classified by (1) regional growth in value added being above or below the median value and (2) the ratio of total freshwater withdrawals in 1965 to median available supplies being above or below the median value. Averages of the magnitudes of interest for each category were computed and are reported in Tables 15 through 17. The price of water to industry cannot be directly measured because most of the water used in industry is self-supplied; according to Census sources, 87.2 percent of freshwater intake and 89.7 percent of total intake came from company sources in 1968. However, it is highly likely that as withdrawals of freshwater, both from surface and ground sources, increase relative to available supplies, the cost of securing an additional unit of water will increase. In other words, increased demand for water relative to supply will, de facto, increase the implicit price of water to industry.

The averages reported in Tables 15 through 17 indicate that the pressure on available supplies of fresh water and growth in value added have provided incentives to industry to economize on water.[3] Intake increased most rapidly for regions which experienced above average growth in production but increased more slowly for regions in which pressures on water supplies were above the average (cf. Table 15). Growth in the ratio of value added to water intake, a measure of the productivity of water in industry, was higher for the faster growing regions and for regions in which water demand relative to supply was above average (cf. Table 16). Recycling and reuse of water is a prevalent method of economizing on industrial water intake. The results in Table 17 indicate that, excluding the Arkansas-White-Red region from the computations,[4] the recycle is a positive function of both growth in product demand and the implicit price of water. Thus, it appears that the incentives for economizing on water in industry are much the same as those for any other industrial input.[5]

An interesting question arises from this conclusion: namely, do the same incentives which, in part, guide industrial water intake and use influence the amount of wastewater treatment performed by industry? Based on the same type of analysis, the answer to this question is negative. Tables 18 through 20 show that there is no consistent pattern among different measures of increases in industrial waste treatment (i.e., the ratio of treated discharge to total discharge in 1968, the growth in the ratio of treated discharge to total discharge from 1959 to 1968, and the growth in treated discharge from 1959 to 1968) and

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[3] There is a high degree of confidence that the ROW averages are different from one another as are the column averages. In the language of the statistician, difference between ROW means and differences between column means are significantly different from zero at the .10 level.

[4] The Arkansas-White-Red region, which had the highest computed recycle ratio among the regions, deviates from the relationship between recycling and the growth in production and the pressure on available freshwater supplies. One possible reason for this deviance is that much of the surface water in this region is acknowledged to be of poor quality which, in turn, increases the need for treatment prior to application. The treatment is an additional cost of using the water which creates an incentive for further recycling.

[5] A multiple regression analysis using value added and the ratio of withdrawals to available supplies as explanatory variables also supports this conclusion.

## TABLE 15

### AVERAGE OF 1968 INTAKE AS A PERCENTAGE OF 1959 INTAKE FOR INDUSTRIAL WATER USE REGIONS CLASSIFIED BY RATIO OF WITHDRAWALS TO MEDIAN WATER SUPPLY AND GROWTH IN VALUE ADDED

| | RATIO OF WITHDRAWALS TO MEDIAN AVAILABLE SUPPLY, 1965 | | ROW MEAN |
|---|---|---|---|
| Growth in Value Added, 1959-68 | Below Median | Above Median | |
| BELOW MEDIAN | 123.5 | 118.9 | 123.5 |
| ABOVE MEDIAN | 158.0 | 121.6 | 140.1 |
| COLUMN MEAN | 141.1 | 120.3 | |

## TABLE 16

### AVERAGE OF 1968 VALUE ADDED/INTAKE AS A PERCENTAGE OF 1959 VALUE ADDED/INTAKE FOR INDUSTRIAL WATER USE REGIONS CLASSIFIED BY RATIO OF WITHDRAWALS TO MEDIAN WATER SUPPLY AND GROWTH IN VALUE ADDED

| | RATIO OF WITHDRAWALS TO MEDIAN AVAILABLE SUPPLY, 1965 | | ROW MEAN |
|---|---|---|---|
| Growth in Value Added, 1959-68 | Below Median | Above Median | |
| BELOW MEDIAN | 101.3 | 113.7 | 107.8 |
| ABOVE MEDIAN | 111.7 | 159.8 | 136.1 |
| COLUMN MEAN | 106.8 | 137.0 | |

## TABLE 17

### AVERAGE OF 1968 RECYCLE RATIO FOR INDUSTRIAL WATER USE REGIONS CLASSIFIED BY RATIO OF WITHDRAWALS TO MEDIAN WATER SUPPLY AND GROWTH IN VALUE ADDED

| | RATIO OF WITHDRAWALS TO MEDIAN AVAILABLE SUPPLY, 1965 | | ROW MEAN |
|---|---|---|---|
| Growth in Value Added, 1959-68 | Below Median | Above Median | |
| BELOW MEDIAN | 1.87[1] | 2.12 | 2.00 |
| ABOVE MEDIAN | 2.53 | 4.80 | 3.67 |
| COLUMN MEAN | 2.20 | 3.46 | |

[1] Excludes Arkansas-White-Red region.

## TABLE 18

### AVERAGE OF PERCENTAGE OF DISCHARGE TREATED, 1968, FOR INDUSTRIAL WATER USE REGIONS CLASSIFIED BY RATIO OF WITHDRAWALS TO MEDIAN WATER SUPPLY AND GROWTH IN VALUE ADDED

| | RATIO OF WITHDRAWALS TO MEDIAN AVAILABLE SUPPLY, 1965 | | ROW MEAN |
|---|---|---|---|
| Growth in Value Added, 1959-68 | Below Median | Above Median | |
| BELOW MEDIAN | 34.5 | 33.2 | 33.9 |
| ABOVE MEDIAN | 31.5 | 35.0 | 33.2 |
| COLUMN MEAN | 33.0 | 34.1 | |

## TABLE 19

### AVERAGE OF 1968 TREATED DISCHARGE AS A PERCENTAGE OF 1959 FOR INDUSTRIAL WATER USE REGIONS CLASSIFIED BY RATIO OF WITHDRAWALS TO MEDIAN WATER SUPPLY AND GROWTH IN VALUE ADDED

| | RATIO OF WITHDRAWALS TO MEDIAN AVAILABLE SUPPLY, 1968 | | ROW MEAN |
|---|---|---|---|
| Growth in Value Added, 1959-68 | Below Median | Above Median | |
| BELOW MEDIAN | 196.0 | 215.7 | 205.8 |
| ABOVE MEDIAN | 376.0 | 255.6 | 315.8 |
| COLUMN MEAN | 286.0 | 235.6 | |

## TABLE 20

### AVERAGE OF 1968 RATIO OF TREATED TO TOTAL DISCHARGE AS A PERCENTAGE OF 1959 FOR INDUSTRIAL WATER USE REGIONS CLASSIFIED BY RATIO OF WITHDRAWALS TO MEDIAN WATER SUPPLY AND GROWTH IN VALUE ADDED

| | RATIO OF WITHDRAWALS TO MEDIAN AVAILABLE SUPPLY, 1965 | | ROW MEAN |
|---|---|---|---|
| Growth in Value Added, 1959-68 | Below Median | Above Median | |
| BELOW MEDIAN | 163.8 | 189.7 | 176.8 |
| ABOVE MEDIAN | 219.3 | 176.8 | 198.0 |
| COLUMN MEAN | 191.6 | 183.2 | |

the growth in value added and the ratio of withdrawals to median available supply. Other regional characteristics, such as regulatory activity, might explain variations in regional differences in industrial wastewater treatment.

Economic behavior, then, leads to process changes which can be expected to decrease industrial waste loadings. At first appearance it might seem paradoxical that increased industrial production and increased pressures on available supplies of fresh water, both of which are pointed to as prime causes of environmental deterioration, also lead to industrial process changes that have--at least relative--environmentallly beneficial effects. The paradox is easily resolved by viewing industrial intake and discharge of water as activities subject to the same set of rational calculations that govern the use of any productive input.

# III

# INDUSTRIAL COST MODEL

## Introduction

The chapter outlines the major assumptions and data sources for the calculation of industrial waste treatment costs presented in subsequent chapters.

## Summation

Industrial waste treatment costs are dependent on flow volumes, residuals characteristics, waste segregation opportunities, and available technology. Although these vary greatly from plant to plant, they can be generalized for industrial categories, and evaluated on the basis of reported flows and flow-to-cost relationships for specified engineering constructs.

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# INDUSTRIAL COST MODEL

## Model Components and Logic

The data and interpretations that constitute the remaining chapters of this report are based largely upon a modelled restructuring of Water Use in Manufacturing. This portion of the Census of Manufactures, 1967 provides a data catalog on the water use characteristics of 9402 manufacturing establishments that reported an intake of 20 million gallons or more of water in 1967, and responded to a detailed questionnaire on their water utilization for the year 1968.

## Model Characteristics

The characteristics of the evaluation model can best be appreciated by a comparison of its aggregated structure with that of the establishments covered in Water Use in Manufacturing, 1967.

The basic distinction between the evaluation model and its Bureau of Census source is the expansion of the model to include establishments with an intake of 10 to 20 million gallons a year, where census data include only users of 20 million gallons or more. The total number of establishments covered is increased by this device by more than 50 percent (cf. Table 21). But in the case of food processing, wood products, and leather, an approximate doubling occurs. These industries tend to be broadly distributed and characterized by moderately- sized plants rather than a few dominant factories (food processing in particular which accounts for 25 percent of the Census-reported sample and 42 percent of the entire expansion in number of modelled factories) so that a truly significant portion of their pollution-associated features are concealed if only larger plants are considered.

A second distinction between the two data structures is critical to the assessment of waste treatment requirements. The manner in which an industry uses water is at least as important to a consideration of its pollution characteristics as is the amount of water it uses; and the distribution of pollution potential--as measured by calculated treatable discharge, which includes process water, sanitary sewage, and cooling water recirculation to process applications--varies significantly from the distribution of total discharge. Pulp and paper production, third in gross water use, becomes the largest source of treatable wastewater, due to the large amount of the industry's intake for processing. Conversely, petroleum refining slips behind food processing

## TABLE 21

## COMPARISON OF CENSUS
## REPORTED ESTABLISHMENT AND
## WATER DATA FOR
## FACTORIES WITH INTAKE ≥ 20,000,000G/YR.
## WITH MODELLED FACTORIES

| SIC | Industry | Percent of Reported Intake | Percent of Calculated Treatable Discharge | Establishments Reported | Establishments Modelled | Difference |
|---|---|---|---|---|---|---|
| 20 | Food & Kindred Products | 5.2 | 8.3 | 2345 | 4494 | +91% |
| 22 | Textiles | 0.9 | 2.1 | 684 | 1021 | +49% |
| 24 | Lumber & Wood Products | 0.8 | 1.9 | 188 | 405 | +116% |
| 26 | Paper & Allied Products | 14.6 | 29.5 | 619 | 862 | +39% |
| 28 | Chemical & Allied | 29.0 | 27.8 | 1125 | 1421 | +21% |
| 30 | Rubber & Plastics | 0.9 | 0.6 | 301 | 459 | +52% |
| 31 | Leather | 0.1 | 0.5 | 92 | 215 | +134% |
| 32 | Stone, Clay, Glass | 1.6 | 2.3 | 586 | 945 | +61% |
| 33 | Primary Metals | 32.6 | 17.8 | 841 | 1137 | +35% |
| 34 | Fabricated Metals | 0.4 | 1.1 | 569 | 1037 | +82% |
| 35 | Machinery | 1.2 | 1.0 | 471 | 790 | +68% |
| 36 | Electrical Equipment | 0.8 | 1.4 | 562 | 817 | +45% |
| 37 | Transportation Equipment | 2.0 | 1.6 | 392 | 562 | +44% |
|  | Manufacturing | 100.0 | 100 | 9402 | 14,499 | +54% |

as a source of treatable wastewater, not so much as a result of the expansion of the food industry's evaluated discharge as because of refineries' relatively heavy use of water for cooling rather than processing. The leather industry--mainly its tanning component--stands out as the one whose relative significance is most affected by the modelling procedure. Heavy use of process water, combined with a large relative number of units with an intake of 10 to 20 million gallons a year, make the industry's share of waste treatment demand five times as great as its reported share of total water demand.

The aggregate impact of these distributional features is not great. Though more than half again as many factories are covered by the evaluation model as by the report of the Bureau of Census, employment in industries covered is only increased by 18 percent, and water use by an even lesser percentage (cf. Table 22). However, the logic of the recirculation device employed in the model, plus the broadening of the population covered, provide a treatable discharge value that not only exceeds reported process intake for plants using 20 million gallons by a gross factor of almost 2.4 to 1, but also exceeds total reported intake for the larger users alone in seven of the fourteen (two digit SIC) industries. It is clear that while a relatively few factories account for the bulk of manufacturers' use of water and for discharge of pollutants, water use technology and size distribution of a number of industries for which water is not so significant a resource tend to conceal a somewhat larger pollution potential than might be thought.

The modelling procedure also affects the interregional distribution of discharges, and so of costs. Not surprisingly, treatment costs for the Colorado, Great Basin, and California regions experience a significant increase in relative dimension when calculated treatable discharge is compared to reported process intake. In those arid areas, resource constraints act to hold an atypical proportion of manufacturers below an intake of 20 million gallons a year, and also to promote recycling. In two of the more humid and less industrialized regions--Southeast and Pacific Northwest--a substantial increase in treatable discharge, as opposed to reported total intake, traces to the presence of a larger number of moderate-sized food processors and a lesser number of wood products factories that would not be included in an evaluation limited to plants with an intake of 20 million gallons or more. These five regions--together with the Western Gulf, where the high degree of recycling characteristic of the petroleum based industries inflates calculated treatable discharge--all experience a significant expansion of indicated waste treatment costs as a result of the procedures employed (cf. Tables 22 and 23).

## TABLE 22

### FLOW & EMPLOYMENT COMPARISON BY U. S. BUREAU OF CENSUS WATER USE REGIONS

| | | No. of Employees | | Total Water Use (BGY) | | | |
|---|---|---|---|---|---|---|---|
| | Water Use Region | Census Reported[1] | Modelled Establishments[2] | Process Intake[1] | Total Intake[1] | Total DSGE[1] | Synthesized Process Discharge[2] |
| 1 | New England | 525800 | 721838 | 245 | 585 | 558 | 459 |
| 2 | Delaware-Hudson | 738500 | 937824 | 228 | 1259 | 1192 | 478 |
| 3 | Chesapeake | 385500 | 447107 | 164 | 816 | 755 | 312 |
| 4 | Eastern Great Lakes | 878700 | 947579 | 413 | 1626 | 1460 | 709 |
| 5 | Ohio | 1014000 | 1284711 | 424 | 2455 | 2295 | 912 |
| 6 | Cumberland-Tennessee | 174600 | 215130 | 117 | 558 | 536 | 209 |
| 7 | Southeast | 686000 | 889309 | 548 | 1181 | 1100 | 1654 |
| 8 | Western Great Lakes | 862400 | 1010992 | 674 | 1924 | 1811 | 1043 |
| 9 | Upper Mississippi | 556100 | 558473 | 200 | 695 | 582 | 359 |
| 10 | Lower Mississippi | 95000 | 124459 | 116 | 780 | 745 | 388 |
| 11 | Missouri | 147300 | 149789 | 67 | 162 | 142 | 146 |
| 12 | Arkansas-Red-White | 168800 | 190533 | 104 | 237 | 185 | 185 |
| 13 | Western Gulf | 244500 | 259663 | 420 | 2031 | 1899 | 2059 |
| 14 | Colorado | 40700 | 45602 | 12 | 23 | 18 | 35 |
| 15 | Great Basin | 17800 | 16939 | 18 | 35 | 27 | 35 |
| 16 | California | 419400 | 579946 | 115 | 370 | 314 | 375 |
| 17 | Pacific Northwest | 209100 | 210695 | 353 | 599 | 533 | 876 |
| | National Totals | 7275600 | 8590589 | 4295 | 15467 | 14276 | 10231 |

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[1] Reported by U. S. Bureau of Census for Establishments with an intake $\geq$ 20 million gallons in 1968.

[2] Developed by E.P.A. for establishments with an intake $\geq$ 10 million gallons in 1968.

## TABLE 23

### FLOW & EMPLOYMENT
### COMPARISONS
### BY INDUSTRY

| SIC | Industry | No. of Employees (1000's) | | Total Water Use (BGY) | | | |
|---|---|---|---|---|---|---|---|
| | | Census Reported[1] | Modelled Establishments[2] | Process Intake[1] | Total Intake[1] | Total DSGE[1] | Synthesized Processes Discharge[2] |
| 20 | Food & Kindred Products | 633.3 | 924.0 | 290.6 | 810.9 | 752.8 | 852.0 |
| 22 | Textiles | 413.5 | 548.5 | 109.0 | 154.2 | 136.0 | 216.6 |
| 24 | Lumber & Wood Products | 63.4 | 149.4 | 36.5 | 117.9 | 92.7 | 193.9 |
| 26 | Paper & Allied Products | 267.6 | 348.5 | 1477.9 | 2252.0 | 2077.6 | 3014.7 |
| 28 | Chemical & Allied Products | 526.8 | 781.9 | 733.4 | 4476.2 | 4175.1 | 2844.3 |
| 29 | Petroleum & Coal | 106.3 | 127.3 | 94.6 | 1435.1 | 1217.0 | 430.3 |
| 30 | Rubber & Plastics | 214.2 | 304.3 | 23.8 | 134.9 | 128.4 | 61.5 |
| 31 | Leather | 32.0 | 102.3 | 13.9 | 15.8 | 14.9 | 51.1 |
| 32 | Stone, Clay, Glass | 224.8 | 325.7 | 89.1 | 251.1 | 218.4 | 239.9 |
| 33 | Primary Metals | 894.5 | 1025.7 | 1027.2 | 5004.7 | 4695.5 | 1821.5 |
| 34 | Fabricated Metals | 357.2 | 586.0 | 37.1 | 67.7 | 65.0 | 110.1 |
| 35 | Machinery | 673.2 | 995.3 | 28.9 | 189.0 | 180.8 | 99.2 |
| 36 | Electrical Equipment | 978.9 | 1254.1 | 46.6 | 126.6 | 118.4 | 139.4 |
| 37 | Transportation Equipment | 1304.0 | 1080.5 | 63.3 | 312.8 | 293.1 | 159.5 |
| | | 7275.6 | 8590.6 | 4295.1 | 15,466.5 | 14,275.9 | 10.231.1 |

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[1] Reported by U. S. Bureau of Census for Establishments with an intake ≥ 20 million gallons in 1968.

[2] Developed by E. P. A. for establishments with an intake ≥ 10 million gallons in 1968.

## Waste Treatment Processes Evaluated

Treatment of the liquid wastes of manufacturing processes is so different in application from sewage treatment that it is very nearly a separate concept. Sewage treatment occurs at the nodal point of a complex of collection and transmission works. Central processing of a relatively homogenous materials input through a sequence of similarly scaled steps is the essence of the method.

Industrial waste treatment, on the other hand, tends to be practiced in terms of the residuals characteristics of separate manufacturing processes. Segregation, rather than collection, of waste streams becomes a prime method of increasing treatment effectiveness and controlling treatment costs. Each waste stream tends to receive only that treatment that is appropriate to its volume and constituents. Uncontaminated waste waters--the prime example is cooling water that does not come into contact with other materials--are segregated and discharged directly or recycled. Complementary waste streams sometimes provide effective treatment without the intervention of any process other than natural mixing--the combination of an acid with an alkaline waste stream, for example, will often provide an appropriate remedial reaction. Even where conventional primary and secondary waste treatment are practiced, it is common that dilute waste streams enter the secondary (biological) stage directly in order to reduce capacity required for sedimentation.

The nature of the procedure has many implications for both industrial water use and for analysis of the costs of industrial waste treatment. (1)Given the significance of segregation of waste streams, there is no configuration of treatment modes that can be assigned as ideal for any group of industrial plants. To some degree, each factory becomes a separate and distinct unit of account, with not only the nature of its processes, but even their physical configuration within the plant dictating the most efficient sequence of liquid waste treatment measures. (2)Because waste streams may be segregated and treated according to waste characteristics, some processes become integral parts of the manufacturing operation rather than waste treatment per se. In effect, the interjection of the treatment process obviates the need for pumping and treatment of fresh intake water and promotes water recycling. (3)Faced with the added cost of waste treatment, management has an incentive to use water more sparingly in other ways than recycling, and may, in fact, abandon some hydraulic processes altogether.

Any consideration of industrial waste treatment, then, must start from the view that it is an integral part of the production process, and must be approached in terms of the general issue of water productivity. From the practical standpoint of analysis, improvements in the productivity of water tend to be distributed through the nation's capital stock in a fashion that is highly influenced by age and location of plants. Because it is such a basic feature of a factory, water engineering does not tend to change, once that factory has been built and is operating. There is, then, good reason to believe that historical trends in reduction of water inputs per unit of product output largely reflect the time stream of plant construction. The same firm can include plants that utilize the water technology of 1871 and 1971--and often the two plants produce the same product and may even be located in the same factory complex.

Quite clearly, the variety of production conditions precludes the development of any precise projection of waste treatment costs for manufacturing, and the wide range of waste treatment possibilities open to industrial management only makes the matter more difficult. It should be recognized, however, that the cost of waste treatment is usually not significant enough in itself to justify major plant redesign, so the capitalization of industrial waste treatment will probably continue for some years to reflect a sub-optimal allocation of resources that derives from the existence of many factories that date from a time before water utilization practices and waste treatment constraints exercised any influence on production costs.

In the absence of reliable decision rules to apply to the complex trade-offs and variations in efficiency that will condition the final cost for any given time period, the model employs the knowledge we possess about the amount of manufacturers' wastes discharges and the characteristics of the water-borne residuals of various manufacturing processes. Using this information, the model attempts to determine with some accuracy the upper limits of such costs and modifications likely to occur as a direct result of the imposition of those costs.

The method of calculation was dependant on the treatment of all process waste streams for each pollutant identified with the process by the most effective (as opposed to most efficient) conventional treatment method now available. And wherever options might be discerned, the higher (or highest) cost solution to the problem was assumed. Consonant with a procedural requirement that all wastes be treated to the highest degree possible with conventional technology, it was assumed that all waste constituents, except dissolved mineral solids, would be removed, reduced, or emended. In effect, it was assumed that floating and settleable materials be removed--with chemical assistance in many cases, that dissolved organics be stabilized, that caustics and acids be neutralized, that potential pathogens be subject to disinfection, that uneven waste streams be equalized, and even--in some particularly difficult situations--that concentrated waste streams be evaporated or incinerated.

Industrial categories reported in Water Use in Manufacturing, 1967 were regrouped into subgroups according to the kinds and concentrations of waste products that were considered to be characteristic of various industrial processes based on an extensive literature. The 320 four digit SIC groupings reported by the Bureau of Census emerged, when reassembled, as 71 components, with a generalized waste treatment configuration established for each (cf. Table 24). The decision rules applied in determining the configuration were:

a. Standardized treatment procedures were to be applied in every case, and where modifications peculiar to a plant or any industry were reported in the technical literature, the modification was rendered in terms of a similar standard solution to the engineering problem.

b. No treatment method, or sequence of treatment methods, drawn from the technical literature was to be applied unless it was associated with a reduction of 90 percent or more of the pollutional aspects of wastewater that it was intended to remedy.

c. All treatment sequences and other system components were to embody the highest cost standard methods; and when there was uncertainty as to what portion of the waste stream was to undergo a given treatment procedure, then the larger possible component--up to the total waste stream--was to be assigned that procedure.

TABLE 24

BASIC ELEMENTS OF THE INDUSTRIAL WASTE TREATMENT MODEL

| INDUSTRIAL CLASSIFICATION | | NUMBER OF ESTABLISHMENTS | | | | | PERCENT OF PROCESS WASTEWATER REQUIRING TREATMENT | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CODE | NAME | 10-19 MGY | ≥ 20 MGY | :1: | :2: | :3: | :4: | :5: | :6: | :7: | :8: | :9: | :10: | :11: | :12: | :13: | :14: | :16: |
| 201 | MEAT PRODUCTS | 189 | 541 | 250. | 2.00 | 1.2 | | 33 | | | 80 | | | 165 | 33 | | | |
| 202 | DAIRY PRODUCTS | 456 | 729 | 250. | 1.00 | 1.2 | | | 50 | | | | | 100 | | | | |
| 203 | CANNED, FROZEN PRESERVED FOODS | 174 | 518 | 200. | 2.00 | 1.2 | | 50 | | | | 100 | | 140 | | | | |
| 2041-5 | FLOUR AND OTHER GRAIN MILL PRODUCTS | 60 | 78 | 250. | 1.00 | 1.2 | | | | | | 100 | | 100 | | | | |
| 2046 | WET CORN MILLING | 4 | 17 | 200. | 3.00 | 1.3 | | 100 | | | | 100 | | 100 | | | | |
| 205 | BAKERY PRODUCTS | 153 | 208 | 250. | 1.00 | 1.2 | | 50 | | | | 100 | | 100 | | | | |
| 2061-2 | CANE SUGAR | 6 | 67 | 150. | 3.00 | 1.35 | | 100 | | 100 | | 200 | | 100 | | | | |
| 2063 | BEET SUGAR | | 60 | 150. | 3.00 | 1.35 | | 100 | | 100 | | 200 | | 100 | | | | |
| 207 | CONFECTIONARY AND RELATED PRODUCTS | 153 | 208 | 250. | 1.00 | 1.2 | | 50 | | | | 100 | | 100 | | | | |
| 208 | BEVERAGES | 239 | 412 | 300. | 2.00 | 1.35 | | 25 | | | | 100 | | 125 | | | | |
| 209 | MISCELLANEOUS FOODS AND KINDRED PRODUCTS | 220 | 300 | 200. | 1.00 | 1.3 | | | | 50 | | 100 | | 100 | | | | |
| 20XX | OTHER FOOD PROCESSING | | | 250. | 1.00 | 1.25 | | 35 | | 25 | | 90 | | 90 | | | | |
| 2211 | WEAVING MILLS, COTTON | 51 | 148 | 250. | 2.00 | 1.2 | | | | 20 | | 100 | | 100 | | | | |
| 2221 | WEAVING MILLS, SYNTHETIC | 29 | 76 | 250. | 2.00 | 1.3 | | 50 | 44 | | | | | 66 | | | | |
| 2231 | WEAVING AND FINISHING MILLS, WOOL | 18 | 82 | 250. | 3.00 | 1.2 | | | | 35 | | 100 | | 100 | | | | |
| 226 | TEXTILE FINISHING, EXCEPT WOOL | 25 | 139 | 250. | 1.00 | 1.2 | | | | 20 | | 100 | | 100 | | | | |
| 22XX | OTHER TEXTILES | 176 | 261 | 250. | 1.00 | 1.2 | | 13 | 11 | 19 | | 64 | | 91 | | | | |
| 24 | LUMBER AND WOOD PRODUCTS | 175 | 231 | 250. | 2.00 | 1.2 | | | | 50 | | 75 | | 100 | | | | |
| 261 | PULP MILLS | 1 | 36 | 350. | 4.00 | 1.35 | | | | 52 | | 43 | | 86 | | | | |
| 2621 | PAPER MILLS, EXCEPT BUILDING PAPER | 6 | 269 | 350. | 2.00 | 1.35 | | | | 40 | | 100 | | 100 | | | | |
| 2631 | PAPERBOARD MILLS | 14 | 185 | 350. | 2.00 | 1.35 | | | | 40 | | 100 | | 100 | | | | |
| 264 | MISCELLANEOUS CONNECTED PAPER PRODUCTS | 59 | 100 | 350. | 1.00 | 1.35 | | | | 60 | | 100 | | | | | | |
| 265 | PAPERBOARD CONTAINERS AND BOXES | 94 | 48 | 250. | 1.00 | 1.2 | | | | | | 100 | | 100 | | | | |
| 266 | BUILDING PAPERS | 5 | 47 | 350. | 2.00 | 1.3 | | | | | | 100 | | 100 | | | | |
| 26XX | MISCELLANEOUS PAPER PRODUCTS | | | 350 | 2.00 | 1.3 | | | | 45 | | 90 | | 100 | | | | |
| 2812 | ALKALIES AND CHLORINE | 1 | 31 | 350. | 1.00 | 1.35 | | 20 | 100 | 60 | | | | | | | | |
| 2813 | INDUSTRIAL GASES | 36 | 82 | 350. | 1.00 | 1.35 | | 20 | 100 | 60 | | | | | | | | |
| 2815 | CYCLIC CRUDES AND INTERMEDIATES | 7 | 64 | 350. | 3.00 | 1.35 | 20 | 25 | 20 | 33 | 67 | | | 100 | | | | |
| 2816 | INORGANIC PIGMENTS | 4 | 27 | 250. | 1.00 | 1.35 | | 20 | 100 | 60 | | | | | | | | |
| 2818 | INDUSTRIAL ORGANIC CHEMICALS | 20 | 147 | 350. | 3.00 | 1.35 | 20 | 25 | 20 | 33 | 67 | | | 100 | | | | |
| 2819 | INDUSTRIAL INORGANIC CHEMICALS | 39 | 198 | 350. | 1.00 | 1.35 | | 20 | 100 | 60 | | | | | | | | |
| 282 | FIBRES, PLASTICS RESINS | 31 | 177 | 350. | 4.00 | 1.35 | | 50 | 15 | 50 | | 100 | | 100 | | | | |
| 283 | PHARMACEUTICALS | 22 | 75 | 250. | 2.00 | 1.2 | | 20 | | 80 | | 65 | | 185 | 60 | | | |
| 284 | TOILETRIES AND DETERGENTS | 41 | 64 | 250. | 1.00 | 1.25 | | | | 33 | 100 | | | 33 | | | | |
| 2861 | PAINTS | 28 | 53 | 250. | 1.00 | 1.25 | | 20 | 100 | 60 | | | | | | | | |
| 2861 | WOOD CHEMICALS | 4 | 19 | 350. | 2.00 | 1.35 | | 25 | 20 | 33 | 67 | | | 100 | | | | |
| 287 | AGRICULTURAL CHEMICALS | 28 | 86 | 350. | 1.00 | 1.35 | | | 20 | 30 | 77 | | 70 | | | | | |
| 289 | MISCELLANEOUS CHEMICAL PRODUCTS | 32 | 116 | 300. | 1.00 | 1.3 | 10 | 20 | 60 | 45 | 23 | | | 50 | | | | |
| 28XX | MISCELLANEOUS CHEMICALS | | | 300. | 1.00 | 1.3 | 10 | 20 | 60 | 45 | 23 | | | 50 | | | | |
| 2911 | PETROLEUM REFINING | 25 | 206 | 350. | 2.00 | 1.35 | 100 | 20 | 40 | 20 | | | | | | | | 130 |
| 29XX | PETROLEUM AND COAL--OTHER THAN REFINING | 35 | 69 | 300. | 1.00 | 1.3 | 40 | 20 | 40 | 20 | 60 | | | 100 | | | | |
| 30 | RUBBER AND PLASTICS | 142 | 317 | 350. | 1.00 | 1.3 | | 50 | 15 | 50 | | 100 | | 100 | | | | |
| 3111 | LEATHER TANNING AND FINISHING | 22 | 88 | 250. | 4.00 | 1.2 | | 100 | 100 | 100 | | | | 100 | | | | |
| 31XX | LEATHER | 77 | 28 | 250. | 1.00 | 1.2 | | | | | 100 | | | 100 | | | | |

**Explanation of Numbered Columns**

:1: Operating Year (Days)
:2: High Waste Concentration Factor
:3: Installation Multiple Factor

**Columns 4 thru 15--Treatment Processes**

:4: Oil Separation
:5: Equalization
:6: Coagulation and Sedimentation
:7: Neutralization
:8: Flotation
:9: Sedimentation
:10: Aeration
:11: Biological Stabilization
:12: Chlorination
:13: Evaporation
:14: Incineration
:15: Activated Sludge

## TABLE 24--continued

## BASIC ELEMENTS OF THE INDUSTRIAL WASTE TREATMENT MODEL

| INDUSTRIAL CLASSIFICATION | | NUMBER OF ESTABLISHMENTS | | | | | PERCENT OF PROCESS WASTEWATER REQUIRING TREATMENT | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CODE | NAME | 10-19 MGY | ≥ 20 MGY | :1: | :2: | :3: | :4: | :5: | :6: | :7: | :8: | :9: | :10: | :11: | :12: | :13: | :14: | :15: |
| 3211-322-3 | GLASS | 36 | 148 | 350. | 1.00 | 1.2 | | | 100 | 100 | | 50 | | | | | | |
| 3241 | CEMENT | 10 | 140 | 350. | 1.00 | 1.2 | | | 100 | 100 | | | | | | | | |
| 325-326 | CLAY | 73 | 51 | 300. | 1.00 | 1.2 | | | 100 | 100 | | | | | | | | |
| 327 | CONCRETE AND PLASTER | 102 | 179 | 300. | 1.00 | 1.25 | | | 100 | 100 | | | | | | | | |
| 3281 | STONE | 10 | 28 | 250 | 1.00 | 1.25 | | | 100 | 100 | | | | | | | | |
| 329 | NON-METALLIC MINERALS | 49 | 121 | 250 | 1.00 | 1.2 | | | 100 | 100 | | | | | | | | |
| 32XX | MISCELLANEOUS--STONE, CLAY, GLASS | | | 250 | 1.00 | 1.2 | | | 100 | 100 | | | | | | | | |
| 3312 | BLAST FURNACES AND STEEL MILLS | 13 | 109 | 350 | 1.00 | 1.35 | 75 | 75 | 100 | 75 | | | | 35 | | | | |
| 331X | STEEL ROLLING AND FINISHING | 35 | 107 | 350 | 1.00 | 1.3 | 75 | 50 | 100 | 75 | | | | | | | | |
| 3321 | GRAY IRON FOUNDRIES | 41 | 76 | 300 | 1.00 | 1.2 | | 50 | | 50 | | 100 | | | | | | |
| 332X | IRON AND STEEL FOUNDRIES | 13 | 109 | 300 | 1.00 | 1.2 | | 50 | | 50 | | 100 | | | | | | |
| 3331 | PRIMARY COPPER | 1 | 26 | 350 | 1.00 | 1.3 | | 100 | 100 | 100 | | | | | | | | |
| 3332-3 | PRIMARY LEAD AND ZINC | 1 | 22 | 350 | 1.00 | 1.3 | | | 100 | 100 | | | | | | | | |
| 3334 | PRIMARY ALUMINUM | | 21 | 350 | 1.00 | 1.3 | | | 60 | 60 | | | | | | 40 | | |
| 33XX | OTHER PRIMARY METALS | 149 | 254 | 300 | 1.00 | 1.3 | | 45 | 70 | 75 | | 30 | | | | | | |
| 34 | FABRICATED METALS | 404 | 633 | 250 | 1.00 | 1.25 | | 56 | 93 | 110 | | | | | 22 | | | |
| 35 | MACHINERY | 281 | 510 | 250 | 1.00 | 1.25 | | 56 | 93 | 110 | | | | | 22 | | | |
| 36 | ELECTRIC MACHINERY | 255 | 562 | 250 | 1.00 | 1.25 | | 56 | 93 | 110 | | | | | 22 | | | |
| 37 | TRANSPORTATION EQUIPMENT | 115 | 447 | 250 | 1.00 | 1.25 | | 56 | 93 | 110 | | | | | 22 | | | |
| 39 | MISCELLANEOUS MANUFACTURING* | 99 | 117 | 250 | 1.00 | 1.25 | | 25 | 40 | 55 | | 47 | 12 | 62 | 5 | | | |

**Explanation of Numbered Columns**

:1: Operating Year (Days)
:2: High Waste Concentration Factor
:3: Installation Multiple Factor

**Columns 4 thru 15--Treatment Processes**

:4: Oil Separation
:5: Equalization
:6: Coagulation and Sedimentation
:7: Neutralization
:8: Flotation
:9: Sedimentation
:10: Aeration
:11: Biological Stabilization
:12: Chlorination
:13: Evaporation
:14: Incineration
:15: Activated Sludge

*Arithmetic mean for all listed industries.

## IV

## COST OF INDUSTRIAL WASTE TREATMENT

### Introduction

The chapter presents the range of capitalization levels and annual costs that have been calculated to coincide with levels of industrial effluent treatment dictated by current interpretations of water quality standards.

### Summation

Through manufacturers' investments to provide waste treatment consistent with current effluent standards may be as high as $12.2 billion (August 1971 = 100), the most likely level of capitalization is roughly $8.3 billion. Annual costs--operation, maintenance, debt service, and replacement--associated with those levels of capitalization are $2.4 billion and $1.6 billion, respectively. Depending on policy flexibility and management skill, the costs are highly controllable, so there are many opportunities to reduce the burden of pollution abatement, both for the firm and for society at large. However, costs are very unevenly distributed, and obsolete factories will bear a share of the total that is disproportionate to either their output or employment. Cost minimizing strategies, then, are likely to produce localized hardship.

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## COST OF INDUSTRIAL WASTE TREATMENT

### Maximum Capital Requirements

Capital facilities having a maximum replacement value of $12.2 billion[1] would be required to provide American manufacturers with the level of waste treatment consistent with current interpretations of State and federal water quality standards. Availability and utilization of that capital would result in maximum annual costs of $2.4 billion (cf. Table 25).

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[1] Dollar values are reported in the text of this study in August 1971 dollars. Tabular data, however, are in all cases presented in the terms in which they were calculated, that is, purchasing power at August 1967 for materials, labor, and equipment in the approximate mix in which they occur in waste treatment plant construction and operation. It should be noted that inflation in the costs of waste treatment plant construction--probably due in large measure to the enormous increase in activity since 1966--has exceeded that in most economic sectors in recent years. During the nineteen-fifties and early nineteen-sixties, waste treatment plant and sewer construction costs rose at an average rate that was less than that of prices generally, and well below that of all construction. Since 1967, such costs--as measured by Sewage Treatment Plant Construction Cost Index--have increased at a materially faster rate than prices generally. And in 1971, when the relative rate of inflation for most items dropped below the experience of 1969 and 1970, the increase accelerated for sewage treatment plant construction.

RELATIVE INFLATION,
MEASURED BY SELECTED PRICE INDICES

| | STP, Construction | GNP Deflator | | Consumer Prices | | |
|---|---|---|---|---|---|---|
| Year | Cost[1] | Structures[2] | Total[3] | All Items | Food | Services |
| 1967 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1968 | 103.5 | 105.1 | 104.0 | 104.2 | 103.6 | 105.2 |
| 1969 | 111.1 | 113.8 | 108.9 | 109.8 | 108.9 | 112.5 |
| 1970 | 120.3 | 122.7 | 114.7 | 116.1 | 114.9 | 121.3 |
| 1971 | 135.7 | 137.4 | 120.4 | 121.3 | 118.4 | 128.4 |

[1] 1967 = 119.4

[2] 1967 = 124.0

[3] 1967 = 117.6

# TABLE 25

## MAXIMUM INDUSTRIAL WASTE TREATMENT REQUIREMENTS 1968 CONDITIONS

| SIC | Industry | Millions of 1967 Dollars<br>Capital Required | Annual Cost<br>Replacement[1] | <br>Interest[2] | <br>Operation |
|---|---|---|---|---|---|
| 20 | Food & Kindred Products | $997.5 | 49.9 | 76.8 | 57.6 |
| | 201 Meat Products | 116.1 | 5.8 | 8.9 | 8.5 |
| | 203 Canned & Frozen Foods | 227.9 | 11.4 | 17.5 | 10.3 |
| | 206 Sugar Refining | 294.2 | 14.7 | 22.7 | 19.9 |
| | 208 Beverages | 112.1 | 5.6 | 8.6 | 5.0 |
| 22 | Textiles | 251.4 | 12.6 | 19.4 | 11.4 |
| 24 | Lumber & Wood Products | 186.1 | 9.3 | 14.3 | 10.1 |
| 26 | Paper & Allied Products | 1550.5 | 77.3 | 119.4 | 112.3 |
| | 261 Woodpulp | 653.8 | 32.7 | 50.3 | 34.3 |
| | 262 Paper | 711.5 | 35.6 | 54.8 | 42.6 |
| | 263 Paperboard | 321.5 | 16.1 | 24.8 | 21.7 |
| 28 | Chemical & Allied Products | 1550.5 | 121.8 | 187.6 | 123.9 |
| | 281 Industrial Chemicals | 1252.4 | 62.6 | 96.4 | 93.6 |
| | 282 Fibers, Plastics, Resins | 144.1 | 7.2 | 11.1 | 8.1 |
| 29 | Petroleum & Coal | 1096.1 | 54.8 | 84.4 | 48.4 |
| | 291 Petroleum Refining | 1083.6 | 54.2 | 83.4 | 47.3 |
| 30 | Rubber & Plastic | 96.0 | 4.8 | 7.4 | 6.1 |
| 31 | Leather | 86.8 | 4.3 | 6.7 | 4.3 |
| 32 | Stone, Clay, Glass | 182.3 | 9.1 | 14.0 | 21.3 |
| 33 | Primary Metals | 1620.5 | 81.0 | 124.8 | 147.3 |
| | 331 Basic Steel Products | 981.8 | 49.1 | 75.6 | 110.6 |
| | 333 Primary Non-Ferrous Metals | 204.6 | 10.2 | 15.8 | 12.9 |
| 34 | Fabricated Metal Products | 1124.14 | 6.2 | 9.6 | 12.6 |
| 35 | Machinery | 100.1 | 5.0 | 7.7 | 10.7 |
| 36 | Electrical Equipment | 129.46 | 6.5 | 10.0 | 14.1 |
| 37 | Transportation Equipment | 122.71 | 6.2 | 9.4 | 15.9 |
| | Manufacturing | 8965.7 | 448.3 | 690.4 | 600.3 |

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[1] 20 year average life.

[2] 7.7% average rate, Moody's Industrials, January-August, 1971.

The amounts--which are based on the 1968 distribution and utilization of productive capital--are gross figures. They include the replacement value of waste treatment facilities already in place, waste treatment services provided by public agencies, and no allowances for relative efficiencies or in-plant modifications that may provide equivalent effects for less cost.

Capital requirements are distributed through the various manufacturing sectors in a manner that strongly reflects their water use characteristics and has loose direct correlation with output values. Chemicals manufacture, primary metals production, pulp and paper production, petroleum refining, and food processing account, respectively, for 27 percent, 18 percent, 17 percent, 12 percent and 11 percent of the indicated investment, and 29 percent, 32 percent, 15 percent, 9 percent, and 5 percent of reported water intake. Eighty-five percent of the capital requirement associated with water pollution abatement, then, comes from five manufacturing sectors that, in the aggregate, provide little more than a third of values added by manufactures.

The association of capital requirements with water use practices has enormous implications for the dimensions of ultimate costs. Higher treatment costs, other things being equal, are a direct consequence of wasteful use of water. And water is wasted largely because it has had many of the characteristics of a free good. Imposition of a wastewater treatment requirement--or other cost-incurring constraint on water utilization--will, it has been demonstrated both in theory and in practice, lead to production practices that are less water-intensive, and thus have lower associated waste treatment values.

In the eventual resolution of the industrial waste-handling situation, it is almost inconceivable that the maximum investments summarized in Table 25 will occur under existing abatement requirements. A significant segment of the total value calculated must be attributed to the fact that a good portion of the investment represented has not been made. When it is made, the process of investment may be expected to lead to a pattern of water utilization that eliminates a significant portion of the cost.

## Variation of Capital Requirements

Several modifications of the evaluation model were attempted in order to arrive at a more realistic assessment of capital requirements, one that took into account the modification of water utilization practices that accompanies installation of waste treatment as well as hardware and construction costs. Without altering the relationships among treatment process components, water use coefficients were substituted for the observed ones--though all substitutions were made by recourse to observed conditions--and investment and annual cost calculations were produced to reflect the altered variables. Table 26 presents distribution of

## TABLE 26

## VARIATION IN CAPITAL REQUIREMENTS UNDER ALTERNATIVE WATER UTILIZATION REGIMENS, 1968 CONDITIONS

| | Capital Requirements | |
|---|---|---|
| Level of Industry Efficiency | Billions of 1967 dollars | Billions of 1967 dollars |
| Actual 1968 distribution | $8.97 | $12.17 |
| Least efficient (17th) regional component given characteristics of directly superior (16th) | 7.57 | 10.27 |
| All efficiencies less than median given characteristics of median component | 5.96 | 8.09 |
| All efficiencies less than most efficient third (6th) given characteristics of sixth component | 4.84 | 6.57 |
| Most efficient component's characteristics used in all cases | 3.12 | 4.23 |

capital requirements in terms of alternative water use regimens. The most likely investment level is thought to be the one associated with median efficiency--certainly somewhere in the range between "most efficient third" and modification of "the least efficient region".

The levels of capitalization thought to define probable requirements were reached by calculating costs for each of 71 industrial subgroups on the basis of water use characteristics of the industry at unit water utilization rates no greater than those characteristic of the median region among the census defined "Industrial Water Use Regions", the sixth in relative efficiency among the seventeen regions, and the sixteenth in relative efficiency. That is, water use rates were utilized precisely as observed for nine regional/industrial components in the one case;in the other cases for six and sixteen regional segments of each industry, with the characteristics of the ninth, the sixth and the sixteenth substituted for those regions in which they are exceeded in reported practice.

The likelihood of achieving such enormous efficiencies--in aggregate terms they amount to $2 to $5 billion worth of waste treatment capital at little or no cost--is not as remote as it might appear on the surface. The substitute variables imposed upon the matrix are not expressed as levels of firm or factory efficiency, but as expressions of existing regional distributions that include all of the parameters--age of plant, processing technique, size of plant, raw material quality, water availability--that affect unit water use in large subsets of a total industry. Further, the range of conditions that is thought to include the most probable set of investments is not extended to less efficient industrial subsets on the basis of the values at the ends of the chosen regional groupings. Costs imposed on the less hydraulically efficient industry/region subsets did not come from a compression of the distributions for the more efficient regions, so do not reflect the more demanding use regimens of arid regions. The manufacturing technologies that are implied, then, lie not only well within the bounds of existing practice, but also within the bounds of practice for areas where there are no significant resource constraints.

In short, the imposed conditions do not represent any theoretical or arbitrary modifications of existing practice, but the extension of practices that are currently employed in substantial segments of each industry. It is not an attempt to discern what would happen if industry made a maximum adjustment of its use of water to accommodate waste treatment, but an attempt to measure what does happen when waste treatment or other cost-imposing constraints on water use occur.

At the risk of redundancy, it should be stressed that the full range of values presented in Table 26 refers to current practice and to an equal degree of waste treatment effectiveness. The values simply provide quantitative expression to the often repeated truism that industry has a number of internal options in dealing with its waste handling problem.

## Policy Implications of Cost Variability

The breadth of the range of values contains some significant policy implications. These should be taken into account in any resolution of the waste handling problem:

1. Alternative approaches to waste reduction requirements can produce similar efficiencies within a wide range of costs. Measures that stress one approach or another to industrial water pollution abatement will inevitably be unsuited to some industry segments, thus will tend to increase costs unnecessarily. Flexibility in approach to the issue should reduce the burden of water pollution abatement on the economy, freeing resources for other uses.

2. Given the significance of flexibility, and accepting the general rule (that underlies all domestic policy on the issue) that management will not act to reduce its discharge of pollutants in the absence of external pressures, it would appear that very direct incentives that embody water quality goals without specifying the means to reach them should provide an approach to a least-cost solution of the waste treatment question. Suitably scaled taxes on amount of waste discharge constituents or limits on allowable pollutant concentrations in the effluent should, for example, prove superior to regulatory specification of treatment procedures.

3. Because the various unit water use values are calculated at the mean for each regional segment of an industry, and because the very wasteful users of water in any industry/region component strongly influence the mean, it is obvious that a relatively few factories--the most inefficient plants in the least efficient regions--account for a very considerable portion of the total cost of water pollution control. A few hundred factories create the almost $2 billion capital gap between the least efficient and next-to-least efficient users. It may be assumed that those plants--mainly engaged in the production of pulp and paper and organic chemicals--are in many cases obsolescent in other respects than their water engineering. That concentration of avoidable costs in a few establishments suggests that factory replacement may in more than a few instances be the most rational solution to waste treatment requirements. The fact that waste treatment does not represent a significant capital burden in the aggregate should not be allowed to obscure the subordinate fact that a number of plants may be scheduled for closure and replacement as a consequence of the very uneven distribution of such costs.

## Annual Cost Components

The matter of initial capitalization of waste treatment works tends to be over-stressed. Granted that installing up to $12 billion worth of facilities represents a significant pressure on management's financial sources and overall capital planning, the first cost of facilities represents less than a fourth of the total cost of industrial waste treatment. Once installed, facilities must be operated and maintained. Given the composition of the set of treatment requirements evaluated here, operation and maintenance accounts for 35 percent of the ultimate total cost. (In the less capital-intensive approach to waste treatment that industry prefers in actual practice, operation and maintenance charges currently amount to 55 percent of annual costs.) Interest, at current rates, accounts for a large, if not the largest, share of annual charges for waste treatment. Some 40 percent of the annual costs of the modelled treatment system, and 27 percent of the annual costs of the system of works that industry reported to be in operation in 1968, can be attributed to interest payments implicit in the value of the capital stock. And to make the sequence of major and minor replacement expenditures required to sustain the stock of physical capital, the firm faces a continuing capital demand, one that is estimated to equal the initial cost within a 20 year period, and to account for 25 percent of the annual costs of the modelled system of waste treatment works.

## Annual Capital Charges

To restrict our view of the costs of industrial waste treatment to the price of installing the devices is to overlook between three-quarters and four-fifths of the total cost and ultimate impact on prices.

That evaluation, it should be noted, is an even more conservative statement of conditions than most industrial spokesmen would accept. Where this report assesses replacement requirements in terms of the 20 year average life that engineers design into facilities, and assesses interest charges at the current rate for industrial bonds, industrial management tends to view investments in terms of capital recovery factors. These vary from industry to industry, and are influenced by the tax laws, but in few cases is it likely that industry sources would accept the moderate rates of capitalization utilized here as being consistent with their financial management practices.

Recognizing that difference in concept, this study attempts to focus on the practical realities of cost rather than the accounting and financial management conventions that interpret reality within a framework of time preferences, tax liability, and public relations pressures. The emphasis here is on likely amount of annual cash flow and not the vagaries of reported profits or anticipated rates of return.

Expenditures for replacement are based on engineering estimates of the mean expected useful life of facilities. The concept evaluated assumes that five percent of the value of the total capital stock of waste treatment works in any industry will, on average, be replaced each year. The assessment is one of maintenance of the physical stock of capital and consequent cash outlays, not on depreciation as that term is used for tax and other reporting purposes. And while any given rate of replacement may infer an unrealistic evenness to the pattern of expectable outlays, the ultimate occurrence of such costs is undeniable.

While there is almost no evidence available upon which to gauge the rate at which replacement of industrial waste treatment works actually takes place, the five percent figure assigned is considered to be reasonable, in that it takes into account the rated operating life of components and the demonstrated industrial preference for short-term application of capital. (Short-term, that is, as compared to public works.) The assumption that assigns the replacement function at a rate that is 25 percent more rapid than that for municipal waste treatment plants is not, then, based on allowable depreciation accounting, but on anticipations that take into account the nature of components, industrial behavior, and the greater quantity and more corrosive nature of typical industrial wastes per gallon of water.

The interest rate that is assigned includes no selectivity or judgement. the Established market rate for industrial instruments is accepted as the appropriate indicator of the cost of capital at any point in time. Thus, the average monthly yield in the most recent twelve month period, (i.e. 7.7 percent July, 1970 to August, 1971) as reported by a standard financial service (Moodys) for industrial bonds, has been applied consistently to evaluate interest charges.

## Operating and Maintenance Costs

Operating and maintenance charges are a function of capital configurations. As assessed in the model, they deviate sharply from estimates of existing operating costs as a percentage of capital values (cf. Table 27).

Such significant differences cannot be attributed to a difference in method. American industry does not report its operating outlays for waste treatment, so both the value and operating costs had to be calculated in essentially the same manner as were targeted goals. Both values were synthesized from the same sets of coefficients. In the case of existing capital, normal cost to size relationships were applied to the various kinds of reported facilities on the basis of the mean capacity for each industry. A number of explanations for the variation in operating cost ratios are available, and these have potential bearing on policy formulation.

1. Current operating ratios may reflect the fact that industrial wastes, in the aggregate, are under-treated. As the degree of waste treatment increases, the process becomes increasingly capital-intensive. Normal economies of scale find expression as the waste treatment process is intensified, but they are less pronounced--at least in terms of the progression pre-treatment, primary treatment, secondary treatment--with respect to capital than for labor costs, which account for roughly half

## TABLE 27

## ANNUAL OPERATING AND MAINTENANCE COSTS AS A FUNCTION OF CAPITALIZATION

| SIC | Industry | Estimated Operating Cost Ratio, 1968<br>Modelled Requirements | Modelled Available Capital |
|---|---|---|---|
| 20 | Food & Kindred | .058 | .076 |
| 22 | Textiles | .045 | .078 |
| 24 | Lumber & Wood Products | .077 | .155 |
| 26 | Paper & Allied Products | .057 | .122 |
| 28 | Chemicals & Allied Products | .079 | .184 |
| 29 | Petroleum & Coal | .060 | .214 |
| 30 | Rubber & Plastics | .056 | .100 |
| 31 | Leather | .050 | .100 |
| 32 | Stone, Clay, Glass | .116 | .075 |
| 33 | Primary Metals | .092 | .162 |
| 34 | Fabricated Metal Products | .091 | .060 |
| 35 | Machinery | .096 | .054 |
| 36 | Electrical Equipment | .098 | .063 |
| 37 | Transportation Equipment | .12 | .063 |
|  | Misc. & Unidentified |  | .050 |
|  | Mean, All Manufacturing | .073 | .147 |

of normal operating costs. Thus all costs rise as degree of treatment increases, but capital costs rise more sharply than operating charges.

2. Capital saving expedients that reduce total costs but increase unit costs by forfeiting economies of scale are probably available in far greater measure than the modelled evaluation indicates. More stringent waste segregation and process water recycling (as opposed to the cooling to process cycles assumed in the model) would permit much smaller waste treatment plants, thus lower capital costs, without a comparable reduction in operating costs.

3. Industry is known to favor waste treatment solutions that minimize capital requirements. There are a number of treatment configurations, and treatment-process combinations, that provide equivalent waste control in any given situation. In approaching a possible trade-off between capital and operationally intensive alternatives, management has every reason to favor the one that promises capital savings up to--and perhaps even beyond--the point of equal total cost:

a. Capital savings may be applied to other purposes; operating economies must be accumulated over time to provide the same utility. Available savings, then, are inherently more valuable than potential ones, with the amount of the premium generally considered to be expressed by the prevailing interest rate (though the return on invested capital anticipated by any firm establishes its particular level of preference). Over the last three to four years--when a significant portion of total manufacturers' investment for waste treatment has taken place--interest rates have held at levels not generally seen in the U.S. since the eighteenth century. Given the consequent penalty on capitalization and expectations for more characteristic interest charges in the future, management has a strong incentive to seek out treatment solutions with low capital requirements--even at the expense of otherwise avoidable operational penalties.

b. The composition of outputs shifts rapidly, and the nature of processes somewhat less rapidly, in a number of industries. Least-cost solutions that are tied too intimately to a particular product or process carry with them a high degree of risk. Management may, in such circumstances, find it preferable to accept operational cost disadvantages in order to insure flexibility. Land intensive and operationally demanding treatment configurations in many cases serve as insurance against sunk capital losses. (The phenomenon is probably most evident in segments of the chemicals industries, where batch processing persists in order to reduce the impact of process change on risk factors, leading management to resist capital intensive continuous flow production processes of inherently greater efficiency.) If the waste treatment system is viewed as an extension of the total production process, it is not surprising that the same risk-avoidance mechanisms should produce the same augmenting effects on operating costs.

c. Taxes on business are framed to make it more advantageous to accept incremental operating costs, all other things being equal. Materials and labor utilized in operations may be used as an offset in the year of the expenditure, while capital must be charged off over time.

There is, then, a wide possible variation in the composition of annual costs. Not only hydraulic efficiency, but trade-offs between capital and operational elements, between equipment and land within the capital costs, and between the capital and operating component of waste treatment practice will affect the resolution of costs.

One may make the simplifying assumption that trade-offs all take place virtually at the point of intersection of marginal cost curves for capital and other factors. If the assumption approximates reality, then costs derived from the evaluation model may be trusted. Unfortunately, there are no data with which to test the assumption. On the other hand, it should be kept in mind that the logic of the model is based upon determining the highest possible costs that are consistent with current waste treatment standards. It is reasonable, then, to assume that annual costs, at any given level of efficiency, will be no greater than those presented here, regardless of the relative weight of operations, replacement, and interest charges. (In the public sector, the bias to capital-intensive solutions created by existing cost-sharing procedures results in unnecessarily high annual costs. Subsidy and other market-limiting arrangements could produce a similar effect in the case of industrial waste treatment. At the present time, however, the cost-ceiling thesis seems generally accurate.)

The product of the evaluation procedure, as reported in Table 28, is the determination that complete adherence by manufacturers to the waste treatment requirements of existing water quality standards would have amounted to something between $1.2 and $1.7 billion of value added by manufactures in 1968, or between $1.6 and $2.4 billion in 1971 prices. (Values added by manufactures in 1968 amounted to $260 billion--including the value of waste treatment provided in that year.)

## TABLE 28

### ANNUAL COSTS OF WASTE TREATMENT UNDER 1968 PRODUCTION CONDITIONS

| | | MILLIONS OF 1967 DOLLARS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1968 Utilization Efficiency | | | Median Efficiency | | | Most Efficient Third | | |
| SIC | INDUSTRY | Operating | Capital[1] | Total | Operating | Canital[1] | Total | Operating | Capital[1] | Total |
| 20 | Food & Kindred Products | 57.6 | 126.7 | 184.3 | 51.5 | 116.0 | 167.5 | 43.5 | 101.1 | 144.6 |
| 22 | Textiles | 11.4 | 32.0 | 43.4 | 10.4 | 29.8 | 40.2 | 9.1 | 27.0 | 36.1 |
| 24 | Lumber & Wood Products | 10.1 | 23.6 | 33.7 | 5.3 | 14.7 | 20.0 | 5.3 | 14.7 | 20.0 |
| 26 | Paper & Allied Products | 112.3 | 196.7 | 309.0 | 86.9 | 156.9 | 243.8 | 75.3 | 138.2 | 213.6 |
| 28 | Chemicals & Allied Products | 123.9 | 309.4 | 433.3 | 71.4 | 110.2 | 181.6 | 45.7 | 75.5 | 121.2 |
| 29 | Petroleum & Coal | 48.4 | 139.2 | 187.6 | 38.1 | 103.8 | 141.9 | 31.4 | 82.2 | 113.6 |
| 30 | Rubber & Plastics | 6.1 | 12.2 | 18.3 | 5.0 | 10.5 | 15.5 | 3.7 | 8.4 | 12.1 |
| 31 | Leather | 4.3 | 11.0 | 15.3 | 4.3 | 11.0 | 15.3 | 4.3 | 11.0 | 15.3 |
| 32 | Stone, Clay, Glass | 21.3 | 23.1 | 44.4 | 17.3 | 19.9 | 37.2 | 14.0 | 17.0 | 31.0 |
| 33 | Primary Metals | 147.3 | 205.8 | 353.1 | 114.7 | 138.4 | 253.1 | 88.9 | 102.2 | 191.1 |
| 34 | Fabricated Metal Products | 12.6 | 15.8 | 28.4 | 9.6 | 12.7 | 22.2 | 8.6 | 11.6 | 20.2 |
| 35 | Machinery | 10.7 | 12.7 | 23.4 | 8.0 | 10.2 | 18.3 | 6.2 | 8.4 | 14.6 |
| 36 | Electrical Equipment | 14.1 | 16.5 | 30.6 | 11.7 | 14.4 | 26.1 | 10.0 | 12.8 | 22.8 |
| 37 | Transportation Equipment | 15.9 | 15.6 | 31.5 | 9.0 | 10.1 | 19.1 | 4.8 | 6.1 | 10.9 |
| | Manufacturing | 600.3 | 1138.6 | 1738.9 | 443.1 | 757.5 | 1200.6 | 350.9 | 615.2 | 966.2 |

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[1] Replacement and Interest

# V

# CURRENT LEVEL OF INDUSTRIAL WASTE TREATMENT COSTS

## Introduction

The chapter evaluates treatment currently provided to industrial wastes by industry-supplied and public waste treatment plants.

## Summation

Though there are significant problems of interpretation, it would seem that in 1968 manufacturers were operating $2.4 billion worth of waste treatment works, and that another $1.5 billion worth of public waste treatment capacity was taken up by manufacturers' wastes.

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## CURRENT LEVEL OF INDUSTRIAL WASTE TREATMENT COSTS

### Evaluation Conditions

It is not possible to gauge beyond the level of gross approximation the degree to which manufacturers as a group currently meet their waste treatment requirements. To compound the difficulties of assessment presented by the various water use, recycling, and process modification options open to management, there are complications presented by use of public waste treatment plants, and the fact that data are reported on industrial investment in a fashion that will not permit consistent calculations.

In general, it would appear that problems of evaluation tend to result in an understatement of the current level of waste treatment, in that waste segregation, internal process adjustments, and use of public facilities are only slightly--if at all--assessable. To counterbalance these forces for under-evaluation is the fact that the only investment data available are those from industry sources, and in the reporting of such data a certain degree of self-serving is almost inescapable. Additionally, there is serious question as to the quality of the capital that is available. Spokesmen for industry admit that at least some of the adjustments to regulation that have been made in the past were in the nature of a minimal response. A portion of the available capital is said to be incompatible with today's more stringent requirements, and so of limited utility. Even if such claims tend to be advanced to support request for relief from regulation in the form of subsidies or time extensions, they cannot be dismissed out of hand.

### Industry-Supplied Treatment

Recognizing those difficulties, it is possible to at least partially evaluate the current replacement value of the waste treatment works that industry reported to be in operation in 1968, using the same generalized cost-to-size coefficients utilized to scale treatment requirements. The procedure provides a value of $2.42 billion for the 6820 treatment components operated by 3521 establishments treating wastewater, as these are cataloged by the Census Bureau (cf. Table 29). The total value of supplied works may be somewhat higher than the calculations suggest, due to the fact that 5881 treatment operations were identified only as "other" than one of the standard treatment procedures (i.e. primary and secondary settling, coagulation, flotation, pH adjustment, aeration, various biological stabilization methods, sand filtration, and chlorination). Judgement and experience suggest, however, that the bulk of the "other" treatments performed consists of screening, flow equalization, and similar rudimentary pre-treatment practices whose costs are calculated as integral components of the defined methods. Total understatement of costs to be attributed to unreported kinds of treatment is probably not significant.

TABLE 29

CURRENT REPLACEMENT VALUE AND ANNUAL COSTS
ASSOCIATED WITH REPORTED INDUSTRIAL WASTE TREATMENT, 1968

| | | MILLIONS OF 1967 DOLLARS | | | | |
|---|---|---|---|---|---|---|
| | | Replacement | ANNUAL COSTS | | | |
| SIC | INDUSTRY | Value | Operation | Interest | Replacement | Total |
| 20 | Food & Kindred Products | 193.8 | 14.8 | 14.9 | 9.7 | 39.4 |
| 22 | Textiles | 48.8 | 3.8 | 3.8 | 2.4 | 10.0 |
| 24 | Lumber & Wood Products | 9.7 | 1.5 | 0.7 | 0.5 | 2.7 |
| 26 | Paper & Allied Products | 529.5 | 64.5 | 40.8 | 26.5 | 131.8 |
| 28 | Chemical & Allied Products | 343.2 | 63.1 | 26.4 | 17.1 | 106.6 |
| 29 | Petroleum & Coal | 342.1 | 73.2 | 26.3 | 17.1 | 116.6 |
| 30 | Rubber & Plastics | 3.0 | 0.3 | 0.2 | 0.2 | 0.7 |
| 31 | Leather | 17.0 | 1.7 | 1.3 | 0.9 | 3.9 |
| 32 | Stone, Clay & Glass | 20.0 | 1.5 | 1.5 | 1.0 | 4.0 |
| 33 | Primary Metals | 216.3 | 35.0 | 16.7 | 10.8 | 62.5 |
| 34 | Fabricated Metal Products | 6.7 | 0.4 | 0.5 | 0.3 | 1.2 |
| 35 | Machinery | 14.8 | 0.8 | 1.1 | 0.7 | 2.6 |
| 36 | Electrical Equipment | 23.8 | 1.5 | 1.8 | 1.2 | 4.5 |
| 37 | Transportation Equipment | 17.4 | 1.1 | 1.3 | 0.9 | 3.3 |
| | Manufacturing | 1787.0 | 263.2 | 137.3 | 72.2 | 472.77 |

The notable thing about the currently available stock of treatment works is, perhaps, its configuration. The reported plants do not generally conform to the high cost set of procedures used in the evaluation model. It has been indicated at several points in this report that there are possible trade-offs between capital and operating costs in the conduct of the waste treatment activity, and that the optimum mix is to be found not at the level of the industry, but at the factory. Given such trade-offs, it is probably reasonable to assess the degree to which any industry fulfills its waste treatment requirements by level of annual costs as well as according to capital availability (cf. Table 30). In those terms, it would appear that American manufacturers in 1968 supplied between 30 and 40 percent of the waste treatment required of them, with enormous variation in degree of compliance to be found between one industry and another.

## Publicly-Supplied Treatment

Both the total deviation from compliance with treatment requirements and the inter-industry variation in degree of compliance shrink when use of publicly supplied waste treatment capacity is taken into account. Eight of the fifteen (two-digit SIC) manufacturing industries discharge a greater volume of wastewater to public sewers--and so, presumably, to public waste treatment plants--than they treat (cf. Table 31). There is a measure of double-counting, in that much of the reported treatment occurs prior to sewering. Unfortunately, the 1967 edition of Water Use in Manufacturing, unlike earlier editions, fails to provide data to assess the extent of the circumstance. To the degree that this use of public facilities provides an effective supplement to the capital supplied by industry itself, it must be considered to reduce the deficiency in industrial waste treatment.

The extent of that supplement must be gauged from very gross and aggregate waste flow data. Thus the best that can be provided is an order of magnitude kind of estimate, one that places the value of public waste treatment capital supplied to industry at $0.9 to $2.2 billion. The range is determined not by differences in conditions but by point of reference, and whether one attempts to judge the value of the public service from the standpoint of its value to the industry that receives it, or from that of the local government that provides it.

Evaluation of Equivalent Service: If one assumes that the value of treatment of a gallon of wastewater is precisely the same in all cases, without regard to who supplies the treatment, then the relationship between reported volume of industrially treated wastes, sewered wastes, and value of waste treatment provided by each industry will provide an evaluation of publicly supplied industrial waste treatment. Table 32 provides such an assessment under the column headed "Equivalent Service". Each of the values in the column was calculated according to the formula:

## TABLE 30

## PERCENTAGE OF REQUIRED WASTE TREATMENT SUPPLIED BY INDUSTRY, 1968

| SIC | INDUSTRY | Percent of Median Requirement | |
|---|---|---|---|
| | | Available Capital | Annual Costs |
| 20 | Food & Kindred Products | 21.2 | 23.5 |
| 22 | Textiles | 20.8 | 24.9 |
| 24 | Lumber & Wood Products | 8.4 | 13.5 |
| 26 | Paper & Allied Products | 42.8 | 54.1 |
| 28 | Chemicals & Allied Products | 39.5 | 58.7 |
| 29 | Petroleum & Coal | 41.8 | 82.5 |
| 30 | Rubber & Plastics | 3.6 | 4.5 |
| 31 | Leather | 19.6 | 25.5 |
| 32 | Stone, Clay & Glass | 12.8 | 10.8 |
| 33 | Primary Metals | 19.8 | 24.7 |
| 34 | Fabricated Metal Products | 6.7 | 5.5 |
| 35 | Machinery | 18.3 | 14.2 |
| 36 | Electrical Equipment | 21.0 | 17.2 |
| 37 | Transportation Equipment | 21.8 | 17.3 |
| | Manufacturing | 29.9 | 39.4 |

## TABLE 31

## VOLUME OF MANUFACTURERS WASTES, SEWERED AND TREATED PRIOR TO DISCHARGE BREAK, 1968

| SIC | Industry | Billion Gallons of Discharge<br>Treated Discharge | Billion Gallons of Discharge<br>Sewered Discharge | Percent<br>Sewered of Treated | Percent<br>Of Total Sewered Discharge |
|---|---|---|---|---|---|
| 20 | Food & Kindred Products | 184.7 | 237.5 | 128 | 23.2 |
| 22 | Textiles | 53.7 | 50.6 | 94 | 5.0 |
| 24 | Lumber & Wood Products | 18.7 | 2.5 | 13 | .2 |
| 26 | Paper & Allied Products | 915.3 | 72.4 | 8 | 7.1 |
| 28 | Chemical & Allied Products | 674.2 | 181.1 | 27 | 17.7 |
| 29 | Petroleum & Coal | 917.7 | 7.5 | 1 | .7 |
| 30 | Rubber & Plastics | 7.3 | 22.4 | 335 | 2.2 |
| 31 | Leather | 9.5 | 10.2 | 107 | 1.0 |
| 32 | Stone, Clay & Glass | 36.3 | 20.4 | 56 | 2.0 |
| 33 | Primary Metals | 1430.9 | 143.3 | 10 | 14.0 |
| 34 | Fabricated Metal Products | 9.0 | 38.6 | 429 | 3.8 |
| 35 | Machinery | 24.5 | 44.5 | 182 | 4.3 |
| 36 | Electrical Equipment | 27.5 | 74.4 | 270 | 7.3 |
| 37 | Transportation Equipment | 22.5 | 77.2 | 343 | 7.6 |
|  | Misc. and Unidentified | 12.7 | 12.8 | 101 | 3.6 |
|  |  | 4353.2 | 1021.6 | 23 | 100.0 |

## TABLE 32

### VALUE AND PERCENTAGE OF INDUSTRIAL WASTE TREATMENT REQUIREMENTS SUPPLIED PUBLICLY IN 1968

|  |  | BASIS OF ESTIMATE |  |  |  |
|---|---|---|---|---|---|
|  |  | EQUIVALENT SERVICE |  | UTILIZED CAPACITY |  |
| SIC | INDUSTRY | $ Millions | Percent of Rqmt. | $ Millions | Percent of Rqmt. |
| 20 | Food & Kindred Products | 249.0 | 27.2 | 381.6 | 40.7 |
| 22 | Textiles | 45.0 | 19.2 | 82.2 | 35.0 |
| 24 | Lumber & Wood Products | 1.3 | 1.1 | 3.3 | 2.9 |
| 26 | Paper & Allied Products | 41.8 | 3.4 | 116.8 | 9.4 |
| 28 | Chemical & Allied Products | 92.0 | 1.1 | 291.1 | 33.5 |
| 29 | Petroleum & Coal | 2.7 | 0.3 | 11.5 | 1.1 |
| 30 | Rubber & Plastics | 9.2 | 11.1 | 36.2 | 43.6 |
| 31 | Leather | 18.2 | 21.0 | 16.4 | 19.0 |
| 32 | Stone, Clay & Glass | 11.2 | 7.2 | 32.9 | 21.0 |
| 33 | Primary Metals | 21.6 | 1.9 | 230.3 | 21.6 |
| 34 | Fabricated Metals Products | 40.3 | 40.4 | 62.5 | 62.6 |
| 35 | Machinery | 26.9 | 33.2 | 70.7 | 67.5 |
| 36 | Electrical Equipment | 64.4 | 56.6 | 120.1 | 116.0 |
| 37 | Transportation Equipment | 59.7 | 74.8 | 125.0 | 157.0 |
|  | Manufacturing | 684.5 | 11.5 | 1644.8 | 27.6 |

$$\left(\frac{G_s}{G_t}\right) C$$

where: $G_s$ = gallons of wastewater discharged by the industry to public sewers in 1968, as reported in Water Use in Manufacturing, 1968;

$G_t$ = gallons of wastewater treated prior to discharge by the industry in 1968;

$C$ = current replacement value of waste treatment facilities provided by the industry in 1968, as calculated by the evaluation model and summarized in Table 29.

The procedure almost certainly results in an understatement of values received, in that the average degree of waste reduction accomplished by municipal waste treatment plants is considerably higher, thus incorporating more capital values, than the average degree of treatment provided by industry itself, if we are to judge on the basis of reported waste treatment procedures available to municipalities and to factories.

Evaluation of Utilized Capacity: If one assumes that the value of waste treatment service provided to industries by local governments is proportional to the amount of their capacity taken up by industrial wastes, then the relationship between total sewage flow, total capacity, non-industrial sewage flow, and value of municipal waste treatment plants will provide an evaluation of the publicly supplied waste treatment capacity devoted to industrial wastes. Table 32 provides such an assessment under the column headed "utilized capacity". Each of the values in the column was calculated according to the formula:

$$\left[\left(\frac{T_v}{T} \times \frac{T_v + T_O - 100P}{T_v + T_O}\right) C\right] \times \frac{S_i}{S}$$

where: $T$ = total municipal waste treatment capacity in 1968, as reported in the Municipal Waste Inventory and summarized in Table 25, Cost Effectiveness and Clean Water ($26.4 \times 10^6$ G/D);

$T_v$ = utilized waste treatment capacity, excluding overloading ($20.8 \times 10^6$ G/D);

$T_O$ = net overloading of waste treatment plants ($2.6 \times 10^6$ G/D);

100 = rule of thumb per-capita sewage discharge;

P = population served by waste treatment ($137 \times 10^6$ persons);

C = current replacement value of municipal waste treatment plants in 1968 as reported in Table 12, Economics of Clean Water ($4,934.4 $\times 10^6$, 1967 = 100)

$S_i$ = sewered discharge for a given industry, as reported in Water Use in Manufacturing, 1968;

S = total sewered discharge of manufacturers.

While the procedure probably gives a better evaluation than does the assessment of equivalent service, there is unquestionably some overstatement to be attributed to inadequate accounting for non-factory discharges in excess of 100 gallons per-capita per day, capitalization in excess of what industry itself would provide for a similar solution (an evaluation of share of annual charges rather than capital shares might obviate the weakness), and the necessity on the part of site-bound plants to discharge uncontaminated waters to sewers where they exercise a demand on available capacity without receiving any effective treatment service.

## Striking a Balance

Clearly, there are enormous uncertainties remaining after the various evaluation procedures have been conducted. Manufacturers' waste treatment requirements in 1968 occupied a range between $4 billion and $12.2 billion. Industry itself supplied between $2.4 billion and $3.1 billion (based on percentage of annual costs) of that amount, and public sources provided an additional $0.9 to $2.2 billion toward the satisfaction of the requirement. At one extreme, it could be stated that the total capital demand was over-supplied; at the other, that only $3.3 billion, or less than a third, had been supplied.

Where the data provide such divergence, interpretation and judgement become necessary. It would appear that (though no single set of conditions can be described as accurate) the most valid estimate of the situation is one that assesses requirements at the median level of efficiency, evaluates industry-supplied treatment on the basis of capital available, and weighs the public sector contribution somewhere between the points provided by capital utilization and equivalent service.

Table 33 hazards such a summation. While the detail is open to serious question, even at the very high level of aggregation employed, the order of magnitude of the components would seem to be highly reasonable: requirements, $8.3 billion; available capital supply, $4.0 billion; unmet demand, $4.3 billion.

## TABLE 33

## INDUSTRIAL WASTE TREATMENT SITUATION SUMMARY, 1968

|  |  | MILLIONS OF 1967 DOLLARS |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  |  | Capital Supplied |  | Median |  | Maximum |  |
| SIC | INDUSTRY | By Industry | Publicly[1] | Requirement | Deficiency | Requirement | Deficiency |
| 20 | Food & Kindred Products | 193.8 | 315.3 | 913.3 | 404.2 | 997.5 | 438.4 |
| 22 | Textiles | 48.8 | 63.6 | 234.8 | 122.4 | 251.4 | 139.0 |
| 24 | Lumber & Wood Products | 9.7 | 2.3 | 115.8 | 103.8 | 186.1 | 174.1 |
| 26 | Paper & Allied Products | 529.5 | 79.3 | 1235.6 | 626.8 | 1550.5 | 941.7 |
| 28 | Chemicals & Allied Products | 343.2 | 191.5 | 867.6 | 332.9 | 2436.8 | 1902.1 |
| 29 | Petroleum & Coal | 342.1 | 7.1 | 817.4 | 468.2 | 1096.1 | 746.9 |
| 30 | Rubber & Plastics | 3.0 | 22.7 | 82.9 | 57.2 | 96.0 | 70.3 |
| 31 | Leather | 17.0 | 17.3 | 86.5 | 52.2 | 86.8 | 52.5 |
| 32 | Stone, Clay & Glass | 20.0 | 22.0 | 156.5 | 114.5 | 182.3 | 140.3 |
| 33 | Primary Metals | 216.3 | 125.9 | 1089.8 | 747.6 | 1620.5 | 1278.3 |
| 34 | Fabricated Metal Products | 6.7 | 51.4 | 99.9 | 41.8 | 124.1 | 66.0 |
| 35 | Machinery | 14.8 | 48.8 | 80.7 | 17.1 | 100.1 | 36.5 |
| 36 | Electrical Equipment | 23.8 | 92.2 | 113.5 | (2.5) | 129.5 | 13.5 |
| 37 | Transportation Equipment | 17.4 | 92.3 | 79.8 | (12.5) | 122.7 | 13.0 |
|  | Manufacturing | 1787.0 | 1131.7 | 5964.2 | 3045.5 | 8965.7 | 6047.0 |

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[1] Mid-point of estimates presented in Table 32.

# VI

# WASTE TREATMENT COSTS THROUGH 1976

## Introduction

The chapter assesses manufacturers' waste treatment investments since 1968, projects investments and annual costs consistent with a policy of full compliance with effluent standards by 1976, and relates those costs to annual cash flow and prices of manufactured goods.

## Summation

On the basis of industry-supplied data, manufacturers investments in the period 1969-1971 roughly doubled the value of industrial waste treatment supplied in 1968. Expressed investment intentions and investments reported for the last four years are generally consistent with--though slightly below--the values thought to be necessary to achieve full effluent treatment compliance by 1976. In total, manufacturers must anticipate a probable cash flow of $20 billion (1971 = 100) over the years 1968-1976, in connection with compliance to effluent standards. While incremental annual costs will probably amount to only about 0.2 percent of aggregate values added by manufacturers, up to 4 percent of total capital spending will be required to comply with standards, and as much as 1 percent of values added in some industries (pulp and paper, steel) will be provided by waste treatment. If additional costs are passed forward to consumers, with full maintenance of margins, prices of manufactured good may increase a little more than 0.1 percent.

# WASTE TREATMENT COSTS THROUGH 1976

## The Situation Since 1968

Although absence of industrial waste data precludes any coherent association of the conditions evaluated in the previous chapter with events of the last three years, it is possible to make some assessment of trends in terms of capital accumulation.

Since 1968, McGraw Hill & Co. has included a survey of pollution control expenditures in its first quarter survey of capital spending intentions. That survey is the only consistent source of information on manufacturers' waste treatment outlays. And though it is presented in aggregate terms that make direct correlation with interpretations derived from Bureau of Census data difficult, it does contain a high measure of authority, and adds considerably to our understanding of evolving conditions.

Taken at face value, the survey indicates that manufacturers' investments for waste treatment have been rising at an almost 20 percent annual rate, after adjustment for inflation, and that reported investment since 1968 is sufficient to have roughly doubled the available capital stock (cf. Table 34).

There are obvious problems in interpreting the data. On the quantitative side, the user runs up against a set of reporting conventions that lists standard industrial classifications by major business of the firm rather than the factory. The vertically integrated firm and the conglomerate make any comparison with the situation summary presented earlier (Table 33) very tenuous. There is not even any assurance that the indicated investments relate to the manufacturing sector; the degree of integration in many predominantly manufacturing firms extends to the conduct of transportation, agriculture, mining. And for the extractive industries it is probably safe to assume that environmental controls in the extraction process (e.g. oil drilling--or even exploration) are as great, or greater, a source of investment demand as are treatment requirements at the factory. Certainly the data reported by the petroleum industry to McGraw Hill & Co. and the American Petroleum Institute's excellent study, 1967 Domestic Refinery Effluent Profile, are consistent with an assignment of major cost at points other than the refinery.

Nor can these dollar amounts be related to specific physical facilities. To what extent they reflect production shifts and process rationalizations that contribute to waste reduction but are in themselves necessary

## TABLE 34

### INVESTMENT, 1969-1971
### (AS REPORTED BY McGRAW HILL & CO.)

MILLIONS OF DOLLARS

| | | 1969[1] | | | | 1970 | | | | 1971[2] | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SIC | | Total | Inflation | Replacement | Net | Total | Inflation | Replacement | Net | Total | Inflation | Replacement | Net | Investment | Net Investment |
| 20 | Food & Kindred | 32 | -3 | -10 | 19 | 46 | -8 | -11 | 27 | 87 | -23 | -13 | 51 | 165 | 97 |
| 22 | Textiles | 7 | -1 | - 2 | 4 | 9 | -2 | - 2 | 5 | 21 | - 6 | - 3 | 12 | 37 | 21 |
| 24 | Lumber & Wood Pdts. | N.A. | | | | N.A. | | | | N.A. | | | | N.A. | N.A. |
| 26 | Paper & Allied | 88 | -9 | -26 | 53 | 94 | -16 | -29 | 49 | 185 | -50 | -32 | 103 | 367 | 205 |
| 28 | Chemical & Allied | 47 | -5 | -17 | 25 | 90 | -15 | -18 | 57 | 133 | -36 | -21 | 76 | 270 | 158 |
| 29 | Petroleum & Coal | 143 | -14 | -17 | 112 | 185 | -31 | -23 | 131 | 227 | -61 | -29 | 137 | 555 | 380 |
| 30 | Rubber & Plastics | 3 | - | - | 3 | 18 | - 3 | - | 15 | 21 | - 6 | - 1 | 14 | 42 | 32 |
| 31 | Leather | N.A. | | | | N.A. | | | | N.A. | | | | N.A | N.A. |
| 32 | Stone, Clay & Glass | 24 | - 2 | - 1 | 21 | 25 | - 4 | - 2 | 19 | 42 | -11 | - 3 | 28 | 91 | 68 |
| 33 | Primary Metals | 115 | -11 | -11 | 93 | 140 | -24 | -16 | 100 | 135 | -36 | -21 | 78 | 390 | 271 |
| 34 | Fabctd. Metal Pdts. | 23 | - 2 | - 5 | 16 | 28 | - 5 | - 5 | 18 | 33 | - 9 | - 6 | 18 | 84 | 52 |
| 35 | Machinery | 20 | - 2 | - 1 | 17 | 39 | - 7 | - 2 | | 53 | -14 | - 3 | 36 | 112 | 83 |
| 36 | Electric Eqpt. | 16 | - 2 | - 1 | 13 | 27 | - 5 | - 2 | 20 | 29 | - 8 | - 3 | 18 | 72 | 51 |
| 37 | Misc. & Unidentified | 96 | -10 | -11[3] | 75 | 140 | -24 | -15[3] | 101 | 109 | -29 | -16[3] | 64 | 345 | 240 |
| | TOTAL | 643 | -64 | -94 | 476 | 87 | -149 | -127 | 596 | 1133 | -305 | -154 | 674 | 2648 | 1746 |

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[1] Distribution between Water and Air Pollution Abatement assumed to be same as reported for 1970.

[2] Planned Investment.

[3] Total replacement--that accounted for in other rows.

or profitable simply cannot be determined. (Though the Conference Board Survey mentioned earlier leads to the inference that roughly 30 percent of the investment is for such purposes.) Nor can the extent to which they include the write-off of properties that are being taken out of production--one of the most convenient means of bringing an obsolescent factory into compliance at a time when a quarter of productive plant and equipment is idle.

The point is not that the reported values published by McGraw Hill & Co. are suspect. There is no reason to infer any lack of credibility. Rather, it should be understood that these data are not consistent with those used elsewhere in this report--they are from a different source, apply to different uses, evaluate separate aspects of the situation.

What is significant about them, in the context of this report, is their magnitude and their trend. They suggest that most segments of manufacturing are investing aggressively for water pollution abatement, and that regulatory incentives as presently structured are securing a healthy response. Attainment of current discharge standards by 1976 is not likely to occur at the mean level and existing distribution of industrial investments since 1968--but if the trend of increase is sustained, and the inter-industry pattern of outlays is modified, the experience of the last three years may be construed as favorable.

## An Investment Schedule

While the water pollution abatement schedule to be met by any industry or any firm represents a diverse mix of compliance order dates, negotiated understandings, and internal decisions, there is an administratively expressed target of full national compliance by 1976. Given more than 14,000 significant manufacturing users of waters and nine years time, there is a nearly infinite number of investment possibilities that are consistent with the target.

The most likely schedule must be assumed to be one that eliminates deficiencies at a fairly even rate, while the processes of growth and replacement assert their effects quite naturally as functions of the capital structure and the rate of economic activity.

Such a schedule, assuming the probable set of costs associated with median hydraulic efficiency and a rate and distribution of output growth for the period 1968-76 similar to that of 1959-68, dictates the investment of $11.2 billion between 1968 and 1976 for treatment of manufacturers' wastes (cf. Table 35).

There is no implication of optimality in the schedule advanced. (And no judgement as to the source of investment, some of which will certainly come from the public sector as a result of industrial discharge to sewers.) It is simply proposed as the most likely response to regulation in the absence of any formal schedule.

TABLE 35

ANNUAL EXPENDITURES CONSISTENT WITH
STANDARDS COMPLIANCE BY 1976
(PROBABLE COST: MEDIAN EFFICIENCY)

| SIC | INDUSTRY | CAPITAL EXPENDITURE,[1] MILLION OF DOLLARS, 1967 1968 | 1969 | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | TOTAL | Capital Required, 1976 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | Food and Kindred Products | 93.8 | 114.7 | 125.5 | 131.4 | 137.4 | 143.4 | 149.5 | 155.6 | 161.9 | 1213.2 | 1102.3 |
| 22 | Textiles | 24.1 | 31.9 | 35.4 | 37.6 | 39.8 | 42.1 | 44.6 | 47.1 | 49.7 | 352.3 | 317.1 |
| 24 | Lumber & Wood Products | 12.4 | 12.4 | 13.3 | 13.7 | 14.2 | 14.6 | 15.1 | 15.5 | 16.0 | 127.2 | 98.9 |
| 26 | Paper & Allied Products | 118.8 | 134.4 | 146.2 | 152.5 | 158.9 | 165.3 | 171.8 | 178.4 | 185.1 | 1411.4 | 1380.9 |
| 28 | Chemical & Allied Products | 65.0 | 110.3 | 123.6 | 134.2 | 146.2 | 160.0 | 176.1 | 195.0 | 217.2 | 1327.6 | 1439.9 |
| 29 | Petroleum & Coal | 72.6 | 79.2 | 85.2 | 88.3 | 91.3 | 94.1 | 97.4 | 100.4 | 103.5 | 812.3 | 872.3 |
| 30 | Rubber & Plastics | 9.5 | 13.5 | 15.0 | 15.9 | 16.8 | 17.7 | 18.6 | 19.6 | 20.6 | 147.2 | 121.3 |
| 31 | Leather | 9.0 | 11.1 | 12.1 | 12.7 | 13.2 | 13.8 | 14.3 | 14.9 | 15.5 | 116.6 | 104.9 |
| 32 | Stone, Clay & Glass | 17.1 | 19.9 | 21.9 | 23.0 | 24.0 | 25.1 | 26.2 | 27.3 | 28.5 | 213.0 | 183.5 |
| 33 | Primary Metals | 112.7 | 162.9 | 182.0 | 194.6 | 208.2 | 222.9 | 238.8 | 256.2 | 275.3 | 1853.6 | 1649.3 |
| 34 | Fabricated Metal Products | 11.2 | 16.2 | 18.0 | 19.0 | 20.1 | 21.2 | 22.4 | 23.5 | 24.7 | 176.3 | 147.4 |
| 35 | Machinery | 8.4 | 9.1 | 9.9 | 10.3 | 10.7 | 11.1 | 11.5 | 11.9 | 12.3 | 95.2 | 85.9 |
| 36 | Electrical Equipment | 11.7 | 15.4 | 16.9 | 17.8 | 18.6 | 19.5 | 20.3 | 21.2 | 22.1 | 163.5 | 147.4 |
| 37 | Transportation Equipment | 8.2 | 9.6 | 10.5 | 10.9 | 11.4 | 11.8 | 12.3 | 12.8 | 13.2 | 100.7 | 92.3 |
|  | Manufacturing | 574.5 | 740.6 | 815.5 | 861.9 | 910.8 | 962.6 | 1018.9 | 1079.4 | 1145.3 | 8110.1 | 7743.4 |
|  | For Comparison: Reported Investment | 416 | 579 | 723 | 828 |  |  |  |  |  |  |  |

[1] Net investment (difference between median requirement and industry-supplied capital at 1968) plus annual growth and replacement.

There is no question that the indicated schedule will be difficult to achieve. Manufacturers are responding to waste treatment requirements at the same time that the public sector is increasing its capitalization of waste treatment works. Total sewerage starts had not reached a billion dollars as late as 1967; but in 1971, manufacturers and municipalities together initiated about $3.0 billion of sewerage and waste treatment contracts. As a consequence of such growth, extreme inflation and lengthening construction schedules have marked this particular component of the construction industry. Whether it can continue to expand sufficiently to meet the schedule, and what price the economy will pay in terms of inflation and quality defects, are probably the critical questions with respect to the waste treatment target.

Unfortunately, there has been little recognition of this really difficult functional problem. Policy formulation in both the public and private sectors has been concerned principally with questions of demand--how much treatment is needed? how much will it cost? and who will pay? Subordinate issues of employment displacement and regulatory mechanics have also been engaged. But in spite of increasing evidence in the form of delayed deliveries, lengthening construction times, and soaring construction costs, the ability of the sewerage construction industry to supply a ballooning demand has never been investigated, and scarcely questioned. There is reason to believe, however, that the supply of suitable construction services will prove far more critical to meeting waste discharge standards by 1976 than will financial commitment.

It should be noted that secular expansion of the level of investment is necessary, even with a constant increment abatement strategy. Growth and replacement demands account for over half of the indicated capital requirement to 1976, and their level is in large measure determined by the dimensions of the capital base. The schedule illustrated in Table 35 may be slightly over-ambitious in that it embodies rates of output growth that applied in one of the most expansionary periods in our history. A slower rate of economic growth would, of course, permit attainment of the target with a lower rate of increase than the 8.9 percent per year dictated by the projection. But internal growth of the system--that is, installation of the treatment capital associated with 1968 output levels--is a more significant influence on the indicated annual level of investment than the external imposition of treatment requirements that arises out of projected production growth.

If we can judge from manufacturers' investments reported by McGraw Hill & Co., the scheduling procedures actually being used by industrial management must adhere fairly closely to the constant increment strategy embodied in the projection. Reported investments since 1968 have advanced at a much faster rate (19 percent a year, exclusive of inflation) than the illustrated schedule, but their approximate dimensions, though somewhat lower, are much the same. This expansion of water pollution abatement investment has been in contrast to total plant and equipment expenditures by manufacturers, which has adopted a slightly downward slope over the last four years when adjusted for price level changes. In consequence, the proportion of total manufacturers' reported investments devoted to waste treatment works has risen from 1.5 percent in 1968, to 2.0 percent in 1969, 2.5 percent in 1970, and an estimated 3.1 percent in 1971.

Given a resumption of the rate of capital accumulation that occurred in the period 1959-68, just under 3 percent of manufacturers' investment must continue to go to waste treatment through 1976 if the target is to be met. But maintenance of a flat pattern of non-inventory investment through 1976 would dictate that an increasingly large share of total investment would be required for the purpose--up to 4 percent, based upon the indicated amount of expenditures for plant and equipment in 1971.

## Manufacturers' Investment Intentions

Not only do reported investments of manufacturers over the last four years indicate a pattern of behavior that is generally consistent with attainment of current waste treatment goals, but also the information we possess with respect to their longer range intentions is not inconsistent with the same purposes.

Again, McGraw Hill & Co. is the source of our information. It has reported "the total cost of bringing industries' (sic) existing facilities up to present pollution control standards as of January 1, 1971," as industrial management has assessed that cost. Unfortunately for the purposes of this report, there is no available distinction between expenditures for air pollution control, water pollution control, and other forms of environmental protection. We are forced to draw inferences from prior experience. There are the additional difficulties of categorization presented by multi-establishment, multi-industry firms. And, unlike the schedule against which these intentions must be compared, there is no statement of time associated with reported dollar values. Nonetheless, the information is useful, and moderately reassuring.

Limiting our consideration to the manufacturing sector, we find that industry in the aggregate is operating on the assumption that an investment of $12.36 billion is required to meet environmental standards (cf. Table 36). Of that, roughly half--on the basis of the recent past--may, perhaps, be allotted to water pollution control projects.

## Table 36

## MANUFACTURERS' ASSESSMENT OF INVESTMENTS REQUIRED TO COMPLY WITH POLLUTION CONTROL REQUIREMENTS, JAN. 1971

(as reported by McGraw Hill & Co.)

| SIC | Industry | Millions of 1970 Dollars | Percent to Water Pollution, 1970-71 |
|---|---|---|---|
| 20 | Food & Kindred Products | 400 | 57% |
| 22 | Textiles | 110 | 34% |
| 24 | Lumber & Wood Products | N.A. | N.A. |
| 26 | Paper & Allied Products | 1,840 | 59% |
| 28 | Chemical & Allied Products | 1,000 | 52% |
| 29 | Petroleum & Coal | 2,120 | 49% |
| 30 | Rubber & Plastics | 300 | 42% |
| 31 | Leather | N.A. | N.A. |
| 32 | Stone, Clay, & Glass | 160 | 40% |
| 33 | Primary Metals | 4,260 | 59% |
| 34 | Fabricated Metal Products | 190 | 50% |
| 35 | Machinery | 690 | 32% |
| 36 | Electrical Equipment | 210 | 51% |
| 37 | Transportation Equipment | 440 | 37% |
|  | Manufacturing | 12,360 | 48% |

There are some distressing inter-industrial divergences from the values produced by the evaluation model, and there are some huge definitional questions. But when the projected investment schedule and the industrial expressions are considered in their most aggregated form, in same year dollars with appropriate situational adjustments, they are very close:

| | | |
|---|---|---|
| Industry intentions (48 percent of total in 1967 dollars) | | $4,372 million |
| Projected capital requirements | $8110 million | |
| Less public capital available, 1968 | (1132 million) | |
| Less reported investment, 1969-71 | (2130 million) | |
| Net capital requirements | | $4,848 million |

The relationship is comforting in the aggregate and on first inspection, if we assume that public treatment of industrial wastes stays fairly constant--but we do not know enough about the values supplied by industry to feel entirely at ease. There is, of course, the inter-industry distribution of intentions as a prime cause of aggravation. But other matters also need to be defined.

1. There is considerable question as to whether the portion of industry's pollution abatement investment that is available for water pollution control will stay constant. Both air and water pollution control expenditures have been rising for a decade, but the relative share to water (where the bulk of the money has gone in the past) has been shrinking. In the early nineteen-sixties, surveys by the National Industrial Conference Board found 60 percent of manufacturers' environmental protection investments devoted to water. In the last half of the sixties, water's share had dropped to 52 percent. And in the last two years, McGraw Hill's data shows water pollution abatement supplying less than half of environmental capital expenditures by industry. Air pollution regulation has become far more stringent, and the general impression is that industrial deficiency in that area is greater. Hence, it seems likely that outlays for water pollution control will continue to decline in a relative sense.

2. Because the values are reported in their least useful form, an aggregated lump, we have little insight into their referents. We do not know if they are for treatment facilities, for reworking processes, for fuel substitutions, for plant abandonment, or any of a host of possible alternatives. Nor do we know if they include investments in 1971 and prior years, or how many years into the future they may include.

3. To what extent the estimates account for anticipated inflation determines to some extent how adequately they will cover the eventual bill. The assumption used in balancing the estimates against indicated requirements was that they represented 1970 constant dollars. There is no hint in the report of the possible validity of that assumption.

The combined weight of these considerations must leave the analyst with some reservations as to whether U.S. manufacturing adequately recognizes the dimensions of the investment it must make for water pollution control over the next five to six years. While the indicated intentions are, on the surface, generally consistent with evaluated requirements--particularly in a context that includes the availability of public facilities and lower cost treatment configurations--there are too many undefined possibilities for shortfall to provide a high measure of satisfaction.

## Cash Flow Implications

To meet the 1976 compliance target will cost American manufacturers between $10 billion and $25 billion between 1968 and 1976. The ultimate amount of direct expenditure will depend principally on the compliance strategy that the preponderance of management adopts. Maximum application of water conserving production process, with an attendant increase in disposition of residuals in dry form, could eliminate more than half of the cost of waste treatment. However, the reduction in the one kind of cost could entail disproportionate increases in other costs, or the application of significantly greater amounts of capital than would be consistent with other investment demands. Persistence of high interest rates would be expected to inhibit realization of a low liquid waste strategy, too, in that such an approach to waste production would probably require very significant recapitalization of existing production facilities.

A high cost strategy would seem as unlikely as one devoted to minimum waste treatment costs. In essence, the highest set of costs associated with industrial waste treatment is predicated on the assumption that industry would meet its waste treatment requirements by simply adding necessary treatment facilities to production conditions in existence in 1968, making no effort to adjust production processes to those treatment facilities or to take indicated water conservation measures to reduce costs.

The probable path to achievement of discharge requirements appears to be at some intermediate route between the two extremes; and the gross magnitude of the manufacturer supplied capital requirements assessment tends to corroborate that judgement. Without significantly recapitalizing existing factories, manufacturers may be expected to make obvious adjustments in water utilization practices to accommodate waste treatment, to close those marginally profitable factories for which adequate waste treatment would impose either a significant incremental investment or serious technical problem, and otherwise to accommodate to discharge limits by providing waste treatment. Over the longer run, new plants may be expected to incorporate cost-reducing water utilization procedures that result in a slightly higher capital to output ratio for the plant as a whole, but a distinctly lower unit cost of waste treatment.

It is that scenario which is felt to be most adequately characterized by the projection of conditions to 1976 that was presented in terms of investment in Table 35.

When that set of conditions is extended to cover interest and operating charges, it suggests the probable expenditure of more than $20 billion by manufacturers for waste treatment between 1968 and 1976 (cf. Table 37). Of that amount, more than half--almost $11 billion--will be required for capital investment to eliminate existing deficiencies, to provide for increased output, and to maintain the capital stock through the replacement process.

The heavy demand for capital is consistent with the significant shortage of waste treatment among manufacturers. However, a part of that capital is being, and will be, supplied through public sources. It might be assumed, then, that actual capital outlays of manufacturers over the period will be somewhat less than is indicated, with operating charges being much greater as a result of payment of user charges to public authorities.

On balance, the use of public facilities could marginally reduce short-term cash flow requirements, in that capital contributions would be engaged through the amortization schedules built into user charges, and thus largely deferred to later years. In addition to relief from cash flow pressures, use of public facilities suggests opportunity to utilize the more advantageous interest rates provided by tax free bonds, to profit from the longer average life (25 years, rather than 20) of the more heavily capitalized plants found in the public sector, and to enjoy the operational cost savings also afforded by higher capital inputs per unit of capacity. (These advantages apply in addition to possible scale economies, the subsidy features provided through State and Federal capital inputs, or the additional subsidies quite often advanced by municipal government in the form of discriminatory user charges or payment for sewerage services from general taxation.)

In spite of those apparent advantages to be obtained by making use of public facilities, only slight reduction of cash requirements is thought likely to eventuate from that source by 1976. The reasons are to be found in technical and institutional aspects of industrial waste treatment.

## TABLE 37

### PROJECTED CASH OUTLAYS ASSOCIATED WITH ATTAINMENT OF DISCHARGE STANDARDS BY 1976
### (MEDIAN EFFICIENCY)

| | | MILLIONS OF 1967 DOLLARS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | OUTLAYS, 1968-1976 | | | | | | Total |
| SIC | Industry | Net Investment | Growth | Replacement | Interest | Operations | Total | 1971 Dollars |
| 20 | Food & Kindred Products | 722 | 189 | 302 | 474 | 413 | 2,100 | 2,850 |
| 22 | Textiles | 186 | 82 | 84 | 131 | 77 | 560 | 760 |
| 24 | Lumber & Wood Products | 99 | -* | 28 | 44 | 26 | 197 | 267 |
| 26 | Paper & Allied Products | 856 | 145 | 410 | 641 | 591 | 2,643 | 3,587 |
| 28 | Chemical & Allied Products | 324 | 572 | 432 | 671 | 729 | 2,728 | 3,702 |
| 29 | Petroleum & Coal | 475 | 55 | 282 | 439 | 265 | 1,516 | 2,057 |
| 30 | Rubber & Plastics | 80 | 38 | 29 | 45 | 36 | 228 | 309 |
| 31 | Leather | 70 | 18 | 29 | 45 | 29 | 191 | 259 |
| 32 | Stone, Clay, Glass | 138 | 27 | 48 | 75 | 108 | 396 | 537 |
| 33 | Primary Metals | 873 | 560 | 421 | 659 | 917 | 3,430 | 4,655 |
| 34 | Fabricated Metal Products | 93 | 48 | 36 | 56 | 70 | 303 | 411 |
| 35 | Machinery | 66 | 5 | 24 | 37 | 48 | 180 | 244 |
| 36 | Electrical Equipment | 90 | 34 | 40 | 62 | 83 | 309 | 419 |
| 37 | Transportation Equipment | 62 | 13 | 26 | 40 | 59 | 200 | 271 |
| | Manufacturing Total | 4,134** | 1,786 | 2,191 | 3,419 | 3,451 | 14,981 | 20,329 |
| | (1971 Dollars) | (5,610) | (2,424) | (2,973) | (4,639) | (4,683) | (20,329) | |
| | Maximum Cost Total | 5,430 | 1,845 | 2,520 | 3,939 | 4,637 | 18,609 | |
| | (1971 Dollars) | (7,369) | (2,504) | (3,420) | (5,345) | (6,292) | (25,252) | |
| | Minimum Cost Total | 1,416 | 880 | 1,267 | 1,976 | 1,792 | 7,322 | |
| | (1971 Dollars) | (1,922) | (1,194) | (1,719) | (2,669) | (2,432) | ( 9,936) | |

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*Rate of improvement in water productivity is greater than rate of growth of output.

**Does not account for publicly supplied waste treatment.

On the technical side, water use and waste treatment requirements are heavily concentrated in a few industries. Of these, both the scale of operations and the nature of wastes in only one, food processing, is generally amenable to conventional sewage treatment. Much of the chemicals industries, and most pulp and paper, petroleum refining, and primary metals industries represent difficult--in some cases insuperable--problems in the context of sewage treatment. Probably, less than half of industrial wastes (though this includes the wastes of the vast preponderance of all factories) could be treated by sewage treatment organizations if circumstances were otherwise generally favorable. A number of institutional factors, however, are so clearly unfavorable that it does not now seem probable that the percentage of industrial wastes that is publicly treated will increase much beyond the current 7-8 percent.

1. The same loss of operational flexibility that motivates manufacturers to avoid heavy capital commitments for waste treatment (even at the expense of higher total costs) causes them to avoid too intimate an association with municipal treatment when liquid waste disposal is a significant feature of factory operations. Limitations on the volume and kinds of wastes that may be discharged to sewers may present a real or potential constraint on operations, or may imply pretreatment costs significant enough to override the advantages of the arrangement. Additionally, it is becoming increasingly common for municipalities to regularize their relationships with discharging factories by long-term contracts that, in protecting the municipality's revenue source, tie the factory to a fixed schedule of payments.

2. Municipal waste treatment works represent only a fraction of the total cost of sewerage, in that the treatment plants are tied to elaborate collection and transmission systems that account for a major share of capital values, and a substantial portion of annual costs. Economies of scale are slight--and may be negative--with respect to collection costs. Yet municipal sewerage systems have in recent years demonstrated a tendency to increase in size and reach. This tendency has carried with it substantial acceleration of replacement charges, as existing plants are abandoned through tie-ins with larger systems. Conforming to the general trend toward more capital intensive municipal waste treatment, the amount of capacity provided per unit of demand has also been rising. Under these circumstances, the manufacturer who connects to a public system does so at the risk of becoming a contributor to revenue demands associated with heavy fixed charges and increasing redundancy.

3. Waste treatment requirements have for some years been evolving in the direction of greater stringency and greater specificity. The principal attraction of the municipal sewerage system to the manufacturer has been the breadth of its application. Elimination of specific contaminants can often be done more easily and more cheaply within the

## TABLE 38

## INCREMENTAL WASTE TREATMENT COSTS RELATED TO VALUES ADDED BY MANUFACTURERS, 1968

| | | Millions of 1967 Dollars | | | | |
|---|---|---|---|---|---|---|
| | | 1968 Conditions | | | | |
| SIC | INDUSTRY | Industry Supplied | Sewer Charges[1] | Total | Increase for Full Compliance | Incremental Value Added |
| 20 | Food and Kindred Products | 39.4 | 46.0 | 85.4 | 82.1 | 0.3% |
| 22 | Textiles | 10.0 | 9.3 | 19.3 | 20.9 | 0.2% |
| 24 | Lumber & Wood Products | 2.7 | 0.4 | 3.1 | 16.9 | 0.3% |
| 26 | Paper & Allied Products | 131.8 | 11.6 | 143.4 | 100.4 | 1.0% |
| 28 | Chemical & Allied Products | 106.6 | 28.0 | 134.6 | 47.0 | 0.2% |
| 29 | Petroleum & Coal | 116.6 | 1.0 | 117.6 | 23.9 | 0.1% |
| 30 | Rubber & Plastics | 0.7 | 3.3 | 4.0 | 11.5 | 0.2% |
| 31 | Leather | 3.9 | 2.5 | 6.4 | 8.9 | 0.3% |
| 32 | Stone, Clay & Glass | 4.0 | 3.2 | 7.2 | 30.0 | 0.3% |
| 33 | Primary Metals | 62.5 | 18.4 | 80.9 | 172.2 | 0.8% |
| 34 | Fabricated Metal Products | 1.2 | 7.5 | 8.7 | 25.7 | 0.1% |
| 35 | Machinery | 2.6 | 7.1 | 9.7 | 8.6 | 0.03% |
| 36 | Electrical Equipment | 4.5 | 13.5 | 18.0 | 8.4 | 0.03% |
| 37 | Transportation Equipment | 3.3 | 13.5 | 16.8 | 2.3 | 0.01% |
| | Manufacturing | 472.7 | 165.3 | 638.0 | 514.8 | 0.2% |

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[1] Calculated from value of capital supplied publicly, Table 33, on basis of mean ratio of sewerage operating costs to treatment plant value at 5.1 percent, 3 percent replacement rate, and interest charge of 6.5 percent.

production process than by waste treatment. Moreover, some of the pollutants that are to be reduced in sewage treatment do not occur in the wastes of all manufacturers (e.g. pathogenic organisms and excess phosphorus). Thus to be tied to a municipal system implies for the plant manager the possibility of paying--and at the margin--for treatment of wastes that he might more cheaply eliminate himself, or which he does not discharge.

These institutional factors should not be expected to eliminate public treatment of industrial wastes, but they should slow materially, if not reverse, the trend toward cooperative waste treatment that has marked the last decade. Site constraints and processing patterns that do not make heavy use of water will probably continue to direct the wastes of most factories into metropolitan sewerage systems. But among the manufacturers who make the largest use of water, cooperative solutions are becoming less and less attractive. Capital shortage and location-induced absence of options are probably the principal remaining incentives for the large industrial user of water to abandon operational control of waste treatment, at this time exceeding both subsidy advantages and the relief from regulatory pressure which had been prime motivating forces in the past.

Given that set of conditions, it is probable that the bulk of the cash requirements associated with industrial waste treatment will be met by industry out of internally generated cash flow or by recourse to financial markets.

The ability of manufacturers to generate the indicated cash flow will probably best be related to total values added by manufacturing. Waste treatment is, after all, nothing more than an additional manufacturing process that confers some incremental utility to purchased materials. It is true that the utility does not flow directly to the user of the product. (Except, perhaps, to the extent that he derives a psychic benefit from the enjoyment of non-polluting characteristics of his consumption pattern.) But the same is true of many of the characteristics of value added. The external character of the particular utility component is in no way different from taxes, advertising, working conditions and wage differentials, or many other components of the value added by the manufacturing process to a particular commodity.

It is clear that a process whose capitalization will require no more than 3 to 4 percent of manufacturers' investments over the next five years will constitute a very small incremental cost, or value added, when the full range of resources that goes into the manufacturing process is taken into account. In the aggregate, the difference between value of waste treatment provided in 1968 and that estimated to be necessary at the probable level of hydraulic efficiency amounts to a 0.2 percent incremental cost (cf. Table 38). (Under the maximum cost of treatment evaluation set, incremental annual costs would amount to 0.4 percent of values added in 1968.)

More significant than the aggregate level relationship, however, is the incidence of added costs among industries. Depending on the significance of water as a raw material and the degree of required treatment already available, the increase in relative costs occupies three orders of magnitude, ranging from .01 percent of values added for transportation equipment up to a full percentage point for pulp and paper.

## Price Level Impacts

It would scarcely seem that cost increases of the dimensions indicated would threaten any industry--not even the paper or primary metals producers who will bear such a significant share of the total cost. But it seems even less likely that management would be satisfied to absorb such costs. If absorbed, the incremental costs in 1968 would have reduced the $53.3 billion (1967=100) pre-tax profits of manufacturers by 0.9 percent, and would have probably imposed a reduction of several percent on low-margined steel, paper, and food processors.

Price increases to cover the additional values conferred are, then, likely. And it is almost equally likely that such increases will be framed in dimensions that are consistent with maintenances of margins. While no technique short of a complex input-output analysis is available to trace the total impact on prices through the transaction chain--and the bulk of the impact is introduced with first stage processors very early in the chain, thus subject to a series of markups before its effect is exhausted in the ultimate retail sale--gross markups can be calculated quite easily, and these are sufficient to sustain order-of-magnitude judgments about impact on the prices of manufactured goods(cf. Table 39).

Giving full expression to calculated markups, and providing not only for recovery of costs but maintenance of margins, such calculations disclose that the costs of incremental waste treatment could have been passed on to consumers in 1968 for little more than a 0.1 percent aggregate increase in the prices of manufactured products. (Manufacturers' sales, in 1967 dollars, are estimated by the Department of Commerce to have been $607 billion in 1968.)

## TABLE 39

## INCREASES IN THE PRICES OF MANUFACTURED GOODS TO BE ATTRIBUTED TO WASTE TREATMENT COMPLIANCE, 1968 CONDITIONS

(Millions of 1967 Dollars)

| SIC | INDUSTRY | Incremental Values Added | Indicated Markup[1] | Price Effect |
|---|---|---|---|---|
| 20 | Food and Kindred Products | 82.1 | .191 | 97.8 |
| 22 | Textiles | 20.9 | .172 | 24.5 |
| 24 | Lumber & Wood Products | 16.9 | .183 | 20.0 |
| 26 | Paper & Allied Products | 100.4 | .238 | 124.3 |
| 28 | Chemical & Allied Products | 47.0 | .396 | 65.6 |
| 29 | Petroleum & Coal | 23.9 | .144 | 27.3 |
| 30 | Rubber & Plastic | 11.5 | .253 | 14.4 |
| 31 | Leather | 8.9 | .202 | 10.7 |
| 32 | Stone, Clay & Glass | 30.0 | .312 | 39.4 |
| 33 | Primary Metals | 172.2 | .213 | 208.9 |
| 34 | Fabricated Metal Products | 25.7 | .234 | 31.7 |
| 35 | Machinery | 8.6 | .226 | 10.5 |
| 36 | Electrical Equipment | 8.4 | .221 | 10.3 |
| 37 | Transportation Equipment | 2.3 | .197 | 2.8 |
|  | Manufacturing | 514.8 |  | 688.2 |

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[1] Values added, less payrolls, divided by value of shipments.

## APPENDIX: THE INDUSTRIAL WASTE TREATMENT MODEL

### Model Components and Logic

The data and interpretations of this report are based largely upon a modelled restructuring of Water Use in Manufacturing. This portion of the Census of Manufactures, 1967 provides a data catalog on the water use characteristics of 9402 manufacturing establishments that reported the intake of 20 million gallons or more of water in 1967, and responded to a detailed questionnaire on their water utilization for the year 1968.

There are significant problems in making use of those data. Every effort is made by the Bureau of Census to avoid the possibility of disclosing information about any respondent, thus the data are aggregated to a degree that makes it impossible to determine directly any but the grossest distributional characteristics of the population presented. Further, the information tends to reflect an emphasis on water as an industrial resource rather than an environmental contaminant. The items reported are in few cases directly useful to the study of pollution control. They must be manipulated within a format of assumptions to yield useful answers for that purpose.

1. The first premise of the model is that the 9402 establishments that were reported upon in Water Use in Manufacturing are too small a number to adequately reflect manufacturers' costs. The Census of Manufacturers, 1967 does not provide any indication of total manufacterers' use of water. However, Water Use in Manufacturing, 1963 did present such data. (Among other things, it reported a total of 10,580 establishments using 20 million gallons or more of water, of which only 8925 responded to detailed questionnaires, suggesting that the 1967 report may also include a less than complete population of plants using 20 million gallons a year). The sample of 9402 establishments was, then, expanded on the basis of the 1963 census to include over 14,000 establishments, that being the greater part of those reported to have an intake of 10 million gallons or more in 1964. (Ten million gallons, assuming a normal five day work week, amounts to a discharge of less than 40,000 gallons per day, or about as much as the sewage from a town of 600 persons - well below the threshold at which sewering is necessary under any but the most unfortunate soil conditions).

2. Having determined that the model should be expanded to include those manufacturing plants that use approximately 10 million gallons or more of water a year, the modellers accepted the premise that waste characteristics have a significant relationship to waste treatment costs. Industrial categories reported in Water Use in Manufacturing, 1967 were then regrouped into subgroups according to the kinds and concentrations of waste products that were considered to be

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characteristic of various industrial processes on the basis of an extensive literature search. The 320 four-digit SIC groupings reported by the Bureau of Census emerged, when reassembled, as 71 components, with a generalized waste treatment configuration established for each.[1] The decision rules applied in determining the configuration were:

a. Standardized treatment procedures were to be applied in every case, and where modifications peculiar to a plant or any industry were reported in the technical literature, the modification was rendered in terms of a similar standard solution to the engineering problem.

(The effect of the rule is to increase calculated costs, in that modifications reported generally relate to a means to reduce costs at an equal or greater treatment efficiency through adaptation to specific conditions.)

(The decision rule was breached for two industry components. In the pulp and paper industry, SIC 26, sulfite waste liquors do not seem adaptable to any of the standard waste treatment procedures. In their case, evaporation and burning prior to treatment of condensates was assigned as an element of the treatment series. In the case of primary non-ferrous metals, SIC 333, the "red mud" wasted in aluminum reduction did not appear to be amenable to any of the standardized waste treatment methods, so evaporation of the liquid component of the slurry was assigned as an element of the treatment series.)

b. No treatment method, or sequence of treatment methods, drawn from the technical literature was to be applied unless it was associated with a reduction of 90 percent or more of the pollutional aspects of wastewater that it was intended to remedy.

c. All treatment sequences and other system components were to embody the highest cost standard methods; and when there was uncertainty as to what portion of the waste stream was to undergo a given treatment procedure, then the larger possible component--up to the total waste stream--was to be assigned to that procedure.

3. Having established a study population--establishments with an intake of 10 million gallons or more of water, distributed through waste and product grouped industrial categories--it was necessary to define the population in terms of size distribution and locational characteristics. The census data do not include such information, so they were disaggregated on the premise that the largest water-using establishments in each of the 320 SIC categories are identical with the largest users of labor in each category.

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[1] Thanks are due to Messrs. Ralph Scott, John Fairall, James Horn, Leon Myers, and Kirk Willard who took time from extremely busy schedules to review the technical aspects of the model and who contributed enormously to such merits as it may have.

Since employment data is as protected by Federal sources as water use data, Dun & Bradstreet files were used to establish distributional characteristics. From the firm's computerized catalog of manufacturers, establishments were drawn from each of the relevant SIC categories on the basis of employment, until a sample population equal to the number of establishments reported to use 10 million gallons or more in 1964 was created. These, with listed employment, are the building block of the model.

4. With location and size distributions of the model components approximated on the basis of the employment surrogate, employment data were translated into hydraulic terms with the use of annual water intake per employee factors derived from Water Use in Manufacturing, 1967. Unfortunately, Census data are not sufficiently detailed to conduct an analysis of water use per employee by location at more than the two digit SIC level of detail, and all available studies of industrial water use indicate that location is equally--if not more--important a determinant of water use as industrial type. To accommodate locational factors, a multiplier was applied to the intake per employee factor, representing the ratio of intake per employee in each of 17 water use regions (designated by the Bureau of Census) to national water use per employee at the 2 digit SIC level. Wasteflow for each of 14,449 modeled establishments was, then, a construct of the formula:

$$Q_a = E \cdot Q_i \cdot Q_r$$

Where: $Q_a$ = annual wasteflow

$E$ = establishment employment, reported by Dun & Bradstreet

$Q_i$ = water discharge per employee, nationally for each of 320 four digit industry categories

$Q_r$ = ratio of regional to national water use per employee in 15 major (2-digit) industry categories

Because wasteflows on an annual basis are of slight significance to design of abatement facilities, annual discharges were further modified by establishing a general divisor for each industry, based on an assessment of average number of working days in the operating year. ($Q = \frac{Q_a}{d}$ Where $d$ = estimated days in working year).

5. Segregation of wasteflows was accommodated at two levels. Census data are reported for purpose of intake--cooling, process, sanitary, boiler feed, and other--and for gross water used, including recirculation, rather than for discharge after type of use. In 1968, for example, less than

28 percent of manufacturers' gross water intake was for process use and 66 percent was for cooling, thus potentially uncontaminated except by heat. Yet it is known that some recycling involves diversion of used cooling waters to process streams, and some cooling involves direct contact with products in process--as in ferrous metallurgy. The modelers were, then, faced with a situation that can be defined only in the very general sense that wastewater requiring treatment is something greater than process water intake, and something less than total discharge.

For the purposes of the model, then, wastewater requiring treatment was defined to be:

$$Q_d = (Q_p \frac{U}{I}) + 30\ E$$

Where $Q_d$ = design flow for treatment system
$U$ = total water use, including recycling
$I$ = total intake
$Q_p$ = process intake
$E$ = employment (i.e. 30 gallons per employee per day for sanitary purpose)

The consequence of the procedure is to establish each factory's treatable discharge in terms that stipulate that recycling of process water is equivalent in degree to total recycle for the industry, with all process recycling accomplished by bringing cooling water into the process stream. Adhering to assumption 2.c, the procedure probably overstates considerably the amount of water requiring treatment. (And, in fact, it was necessary in calculation to set constraints that limited treatable discharge for any component to the amount of its total discharge.)

The values for daily wasteflow requiring treatment were then multiplied by factors intended to give effect to (a) proportion of treatable wastewater requiring a given method of treatment, (b) costs based on flow to cost relationships for construction and operation of the given normal waste strength[2] and, (c) a factor intended to provide an

---

[2] Strengths were gauged in terms of concentration multiples (e.g. $BOD_5$ 400 MG/L = 1), and the multiple became a simple multiplier of flow to be treated (e.g. $BOD_5$ 400-800 MG/L = 2). Economies of scale were, however, taken into account at a level slightly more conservative than the six-tenths power rule, so:

| If Multiplier is: | Treatable Flow is | Where Flow 0.6 Would Be |
|---|---|---|
| 1 | 1 | 1 |
| 2 | 1.6 | 1.5 |
| 3 | 2.2 | 1.9 |
| 4 | 2.8 | 2.3 |

approximation of non-recurring installation cost imposed by land purchase, repiping, and production losses ranging from .2 to .35 times construction cost, depending on the complexity of the hydraulic engineering characteristic of an industry. The sums of individual factory component are able according to SIC grouping (one to four digit), location (county, State, water use region, nation), or waste treatment process. Substitution of alternative flow, treatment, and cost variables allows assessment of impact of policy or technological changes at any level from a single factory to all manufacturing.

Table 24, Chapter III, Part I, presents the elements of the basic industry matrix utilized in the model. Table A presents the cost-to-flow equations and examples of costs associated with selected flow values.

Water Use in Manufacturing, 1967 also provided the information upon which current capitalization estimates were based. The document reports number of plants and volume of flow in a variety of treatment categories for industrial sectors, On the basis of previously established operating rates and the same set of cost functions used to determine requirements, existing facilities were evaluated in terms of average daily flows through facilities of specified types.

It should be noted that--quite apart from distortions involved in assessments at the mean--the procedure significantly understates the degree of required capital that is currently available in many industries. In addition to facilities operated by plants using less than 20 million gallons, wastes discharged to public sewers and treated by public sewage treatment facilities are not accounted for; and in a number of cases, governmental bodies, through the normal sewage handling systems, accepted a major part of an industry's discharge. Nor can wastes discharged to land (septic tanks, irrigation, deep-well disposal) be accounted for in financial terms. In either case, the Bureau of Census simply does not provide sufficient information to permit an evaluation[3].

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[3] A possible offset to this understatement has been suggested by a number of industrial sources who have stated quite freely that much of the treatment capital currently available is under-designed and has been under-maintained. Its operational utility may be considerably less than its current replacement value would suggest.

## TABLE A

## COST TO FLOW RELATIONSHIPS, BASIC WASTE TREATMENT PROCESSES

| TREATMENT PROCESSES<br>CC- CAPITAL COST<br>OM- OPERATION & MAINTENANCE COST | | COST COEFFICIENTS<br>LOG(COST) = A+LOG(FLOW)(B+LOG(FLOW)) | | | COST IN DOLLARS<br>FLOWS IN MILLION GALLONS PER DAY | | | |
|---|---|---|---|---|---|---|---|---|
| | | A | B | C | 0.10 | 1.0 | 10.0 | 100.0 |
| CC | OIL SEPARATION | 4.74702 | 0.92044 | 0.22190 | 10976. | 55849. | 789514. | 31009875. |
| OM | OIL SEPARATION | 0.64345 | -0.17671 | 0.0 | 2313. | 15399. | 102519. | 682492. |
| CC | EQUALIZATION | 4.62325 | 0.74646 | -0.22358 | 7529. | 42000. | 234266. | 1306682. |
| OM | EQUALIZATION | -0.30103 | -0.51016 | 0.06646 | 660. | 1750. | 6299. | 30800. |
| CC | COAGULATION-SEDIMENTATION | 5.52401 | 0.61843 | 0.00042 | 62035. | 334202. | 1415337. | 6230809. |
| OM | COAGULATION SEDIMENTATION | 0.06923 | -0.11755 | 0.00586 | 3441. | 25099. | 200266. | 1590832. |
| CC | NEUTRALIZATION | 4.69097 | 0.90563 | -0.52716 | 5168. | 50000. | 483693. | 4679182. |
| OM | NEUTRALIZATION | 0.24304 | -0.10083 | 0.0 | 772. | 6125. | 48559. | 384988. |
| CC | FLOTATION | 4.59106 | 0.44964 | -0.02748 | 13349. | 38999. | 109824. | 309271. |
| OM | FLOTATION | 0.64345 | -0.17671 | 0.0 | 2313. | 15399. | 102519. | 682492. |
| CC | SEDIMENTATION | 5.45009 | 0.55368 | 0.0 | 79824. | 282416. | 1010578. | 3616179. |
| OM | SEDIMENTATION | 0.64345 | -0.17671 | 0.0 | 2313. | 15399. | 102519. | 682492. |
| CC | AERATION | 4.54407 | 0.23408 | 0.0 | 20416. | 35000. | 59999. | 102856. |
| OM | AERATION | -0.30103 | -0.51016 | 0.06646 | 660. | 1750. | 6299. | 30800. |
| CC | BIOLOGICAL OXIDATION | 5.07555 | 0.643000 | 0.0 | 27073. | 119000. | 523058. | 2299058. |
| OM | BIOLOGICAL OXIDATION | 0.09934 | -0.36057 | 0.07879 | 1200. | 4399. | 22994. | 172753. |
| CC | CHLORINATION | 4.17609 | 0.66317 | 0.0 | 3257. | 14999. | 69065. | 318002. |
| OM | CHLORINATION | 0.24304 | -0.10083 | 0.0 | 772. | 6125. | 48559. | 384988. |
| CC | EVAPORATION | 6.11227 | 1.0000 | 0.0 | 129500. | 1295000. | 12950007. | 129500076. |
| OM | EVAPORATION | -0.7112 | -0.24314 | 0.0 | 520. | 2971. | 16974. | 96976. |
| CC | INCINERATION | 5.83373 | 0.64339 | 0.0 | 155002. | 681914. | 2999991. | 13198057. |
| OM | INCINERATION | 1.57978 | -0.37205 | 0.0 | 31325. | 132998. | 564674. | 2397441. |

## Model Characteristics

The characteristics of the evaluation model can best be appreciated by a comparison of its aggregated structure with that of the establishments covered in Water Use in Manufacturing, 1967.

The basic distinction between the evaluation model and its Bureau of Census source is the expansion to include establishments with an intake of 10 to 20 million gallons a year. The total number of establishments covered is increased by this device by more than 50 percent (cf. Table 21, Chapter III, Part I). But in the case of food processing, wood products, and leather, an approximate doubling occurs. These industries tend to be broadly distributed and characterized by moderately-sized plants rather than a few dominant factories--food processing in particular, which accounts for 25 percent of the Census-reported so that a truly significant portion of their pollution associated features is concealed if only larger plants are considered.

A second distinction between the two data structures is critical to the assessment of waste treatment requirements. The manner in which an industry uses water is at least as important to a consideration of its pollutional characteristics as is the amount of water it uses; and the distribution of pollutional potential--as measured by calculated treatable discharge--varies significantly from the distribution of total discharge. Pulp and paper production, third in gross water use, becomes the largest source of treatable wastewater, due to the heavy portion of the industry's intake for processing. Conversely, petroleum refining slips behind food processing as a source of treatable wastewater, not so much as a result of the expansion of the food industry's evaluated discharge as because of refineries' relatively heavy use of water for cooling rather than processing. The leather industry--mainly its tanning component--stands out as the one whose relative significance is most affected by the modelling procedure. Heavy use of process water combined with a large relative number of units with an intake of 10 to 20 million gallons a year make the industry's share of waste treatment demand five times as great as its reported share of total water demand.

The aggregate impact of these distributional features is not great. Though more than half again as many factories are covered by the evaluation model as by the report of the Bureau of Census, employment in industries covered is only increased by 18 percent, and water use by an even lesser percentage (cf. Table 22, Chapter III, Part I). However, the logic of the recirculation device employed in the model, plus the broadening of the population covered, provides a treatable discharge value that not only exceeds reported process intake for plants using 20 million gallons by a gross factor of almost 2.4 to 1, but also exceeds total reported intake for the larger users alone in seven of the fourteen (two digit SIC) industries. It is clear that factories account for the bulk of manufacturers' use of water and for discharge of pollutants. Water use technology and size distribution of a number of industries for which water is not so significant a resource tend to conceal a somewhat larger pollution potential than might be thought.

(The principal weakness of employment as a water use determinant can be noted in Table 23, Chapter III, Part II. Employment, and thus calculated discharge, in transportation equipment [SIC 37] is significantly less for the evaluation model than for reported users of 20 million gallons or more. Examination of components derived from Dun & Bradstreet reports leads to the inference that aircraft factories consigned to the transportation equipment industry by the Bureau of Census may have been reported by Dun & Bradstreet in the ordinance category. The understatement has little influence on aggregate values for manufacturing presented in this report. The user should be aware, however, that in the case of transportation equipment, total costs are probably under-represented throughout, and by 17 percent or more, if relative employment is a guide.)

The modelling procedure also affects the interregional distribution of discharges, and so of costs. Not surprisingly, the Colorado, Great Basin, and California regions experience a significant increase in relative dimension when calculated treatable discharge is compared to reported process intake. In those arid areas, resource constraints act to hold an atypical proportion of manufacturers below an intake of 20 million gallons a year, and also to promote recycling. In two of the more humid and less industrialized regions--Southeast and Pacific Northwest--a substantial increase in treatable discharge, as opposed to reported total intake, traces to the presence of a larger number of moderate-sized food processors and a lesser number of wood products factories that would not be included in an evaluation limited to plants with an intake of 20 million gallons or more. These five regions, together with the Western Gulf where the high degree of recycling characteristic of the petroleum-based industries inflates calculated treatable discharge, all experience a significant expansion of indicated waste treatment costs as a result of the procedures employed (cf. Table 22, Chapter III, Part II).

## TABLE B

## EVALUATION OF INDUSTRIAL WASTE DISPOSAL PRACTICES, 1968

| SIC | $1,000's in Place (1967=100) Capital | Annual O&M | O&M Ratio | Percent Discharge to Sewers & to Ground |
|---|---|---|---|---|
| 20X | 2,247.4 | 150.9 | 6.7 | X |
| 201 | 40,490.0 | 3,344.8 | 8.3 | 70.1% |
| 202 | 2,358.0 | 96.6 | 4.1 | 62.1 |
| 203 | 57,800.0 | 4,200.0 | 7.3 | 47.6 |
| 204 | 2,691.7 | 192.0 | 7.1 | 40.2 |
| 2046 | 2,202.4 | 137.7 | 6.3 | 27.1 |
| 205 + 7 | -- | -- | -- | 37.1 |
| 206 | 17,857.0 | 1,492.5 | 8.4 | 42.6 |
| 2063 | 54,270.0 | 4,229.0 | 7.8 | 26.0 |
| 208 | 4,914.0 | 462.8 | 9.4 | 55.7 |
| 209 | 8,997.0 | 443.9 | 4.9 | 39.2 |
| 20 | 193,827.5 | 14,750.2 | 7.6 | 47.7 |
| 22X | 9,633.9 | 582.7 | 6.0 | 60.5 |
| 221 | 10,851.0 | 768.0 | 7.1 | 25.6 |
| 222 | 9,051.0 | 625.6 | 6.9 | 41.3 |
| 223 | 9,590.0 | 771.1 | 8.0 | 26.2 |
| 226 | 9,635.0 | 590.9 | 6.1 | 33.5 |
| 22 | 48,760.9 | 3,338.3 | 6.8 | 39.1 |
| 24 | 9,652.2 | 704.2 | 7.3 | 9.2 |
| 26X | 2,958.0 | 370.0 | 12.5 |  |
| 261 | 64,390.0 | 20,510.0 | 31.9 | 1.1 |
| 262 | 271,072.0 | 48,873.0 | 18.0 | 4.4 |
| 263 | 180,824.0 | 31,003.8 | 17.1 | 6.1 |
| 264 | 5,979.0 | 618.8 | 10.3 | 29.8 |
| 265 | -- | -- | -- | 48.9 |
| 266 | 4,247.0 | 654.0 | 15.4 | 14.4 |
| 26 | 529,470.0 | 102,029.6 | 19.3 | 4.6 |
| 28X | 3,092.7 | 256.3 | 8.3 |  |
| 2812 | 13,950.0 | 2,247.0 | 16.1 | 13.5 |
| 2813 | 247.0 | 9.5 | 3.8 | 4.4 |
| 2815 | 37,882.8 | 3,370.2 | 8.9 | 7.5 |
| 2816 | 6,848.7 | 397.7 | 5.8 | 0.4 |
| 2818 | 105,361.0 | 11,540.1 | 11.0 | 2.8 |
| 2819 | 36,803.0 | 2,794.0 | 7.6 | 20.8 |
| 282 | 103,220.0 | 11,293.0 | 10.9 | 3.2 |
| 283 | 8,427.2 | 463.7 | 4.4 | 18.7 |
| 284 | 490.8 | 28.3 | 5.8 | 20.1 |
| 285 | 259.0 | 8.7 | 3.4 | 71.0 |
| 286 | 2,782.0 | 148.1 | 5.3 | 4.2 |
| 287 | 10,232.0 | 1,034.0 | 10.1 | 2.1 |
| 289 | 13,628.9 | 838.2 | 6.2 | 7.3 |
| 28 | 343,225.1 | 34,428.8 | 10.0 | 6.9 |
| 29X | -- | -- | -- |  |
| 29(1) | 342,078.5 | 73,217.5 | 21.4 | 2.6 |
| 30 | 2,979.0 | 287.3 | 9.6 | 19.7 |
| 31X | -- | -- | -- | -- |
| 3111 | 16,972.0 | 1,704.0 | 10.0 | 69.6 |
| 32XX | 1,807.3 | 141.7 | 7.8 | (326) 55.0<br>(322) 35.0 |
| 321 | 6,191.0 | 355.6 | 5.7 | 6.6 |
| 324 | 2,120.0 | 145.3 | 6.9 | 6.4 |
| 325 | -- | -- | -- | 60.0 |
| 327 | 3,170.0 | 160.5 | 5.1 | 9.3 |
| 329 | 6,759.7 | 762.1 | 11.3 | 25.9 |
| 32 | 20,048.0 | 1,565.2 | 7.8 | 15.1 |
| 33X | 13,878.0 | 1,318.1 | 9.5 |  |
| 3310 | 33,384.0 | 2,621.2 | 7.9 | 2.8 |
| 3312 | 156,635.0 | 32,384.0 | 20.7 | 2.5 |
| 332X | 1,379.0 | 66.8 | 4.8 | 40.4 |
| 3321 | 4,074.0 | 320.8 | 7.9 | 43.0 |
| 3331 | 1,790.0 | 70.8 | 4.0 | 37.4 |
| 3332 & 3 | -- | -- | -- | 9.8 |
| 3334 | 5,202.3 | 265.1 | 50.9 | 5.2 |
| 33 | 216,342.3 | 37,046.8 | 17.1 | 4.2 |
| 34 | 93,614.2 | 6,151.1 | 6.6 | 64.7 |
| 35 | 14,779.6 | 765.2 | 5.2 | 25.7 |
| 36 | 23,849.0 | 1,527.0 | 6.4 | 65.8 |
| 37 | 17,358.0 | 1,097.6 | 6.3 | 28.3 |
| 39 | 885.0 | 44.5 | 5.0 | 43.8 |

## PLANNED CONSTRUCTION OF MUNICIPAL WASTE TREATMENT FACILITIES

### Introduction

The purpose of this part of the report is to:

- present results of the 1971 survey of planned construction activities for the period FY 1972 through FY 1976,
- present an estimate of planned construction activity derived by the facilities evaluation model,
- compare the 1970 and the 1971 surveys,
- compare the model and the survey approaches,
- consider how the construction industry capacity might bear on the interpretation of the two estimates for 1971,
- summarize other findings of the 1971 survey with regard to federal/State requirements, type of facilities, user charges, and employee requirements,
- and, finally summarize the program accomplishments in the municipal treatment sector.

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## Survey of Planned Construction for Municipal Waste Treatment Facilities

The 1971 survey was conducted to update EPA estimates of the scope and cost of construction of municipal waste treatment facilities, planned through FY 1976, which communities intend to install to meet current water quality standards implementation schedules or other current standards or enforcement requirements.

The survey was directed to 2294 municipalities whose population was greater than 10,000 persons or whose facilities were serving more than 10,000 persons. The response rate was excellent with 95.5 percent of the survey questionnaires returned (cf. Table 1). The survey details and instructions are included in Volume II of this report.

### Survey Findings

Summaries and analysis of the various elements of data obtained through the survey from the 2300 cities contacted are presented below.

The estimated total cost of constructing planned waste treatment facilities for the five-year period FY 1972 through FY 1976 for municipalities of or serving 10,000 or more persons is just over $14.0 billion. This estimate is based on 1971 construction costs of treatment plants, outfalls, interceptors, and pumping stations. When the construction activity for communities less than 10,000 is included, $18.1 billion in projects is planned over the period FY 1972 through FY 1976. These intentions for FY 1972 through FY 1976 are as follows:

| FY | $ Billion |
|---|---|
| 1972 | 5.28 |
| 1973-1974 | 9.28 |
| 1975-1976 | 3.52 |
| Total | 18.08 |

Table 2 presents a summary of the survey portion of the $18.1 billion estimate. The State-by-State summary of the FY 1972 through FY 1976 intentions shown above is presented in Table 3.

The survey provides an assessment of intended State activities. In recording recognized improvements, individual communities tend to be optimistic in the amount of construction activity that will take place so that the collective expectations of local communities may be greater than the ability of the construction sector to supply these needed facilities. In later years the figures could be less accurate because many communities do not yet have detailed plans and specifications for these facilities.

## TABLE 1

## SUMMARY OF SURVEY RESPONSES

| | Number of Municipalities Contacted | Number of Responses | Percent Response | Number of Responses Indicating Needs |
|---|---|---|---|---|
| TOTALS | 2294 | 2191 | 95.5 | 1435 |
| REGION I | 174 | 174 | 100.0 | 82 |
| Connecticut | 48 | 48 | 100.0 | 20 |
| Maine | 17 | 17 | 100.0 | 11 |
| Massachusetts | 85 | 85 | 100.0 | 38 |
| New Hampshire | 7 | 7 | 100.0 | 7 |
| Rhode Island | 13 | 13 | 100.0 | 6 |
| Vermont | 4 | 4 | 100.0 | 0 |
| REGION II | 204 | 187 | 91.6 | 119 |
| New Jersey | 103 | 93 | 90.2 | 53 |
| New York | 100 | 93 | 93.0 | 65 |
| Puerto Rico | 1 | 1 | 100.0 | 1 |
| Virgin Islands | -- | -- | -- | -- |
| REGION III | 302 | 288 | 95.3 | 190 |
| Delaware | 2 | 2 | 100.0 | 2 |
| Maryland | 21 | 21 | 100.0 | 18 |
| Pennsylvania | 215 | 201 | 93.4 | 120 |
| Virginia | 44 | 44 | 100.0 | 33 |
| West Virginia | 19 | 19 | 100.0 | 16 |
| Dist.of Columbia | 1 | 1 | 100.0 | 1 |
| REGION IV | 323 | 317 | 98.1 | 247 |
| Alabama | 39 | 39 | 100.0 | 26 |
| Florida | 85 | 85 | 100.0 | 71 |
| Georgia | 41 | 41 | 100.0 | 27 |
| Kentucky | 30 | 25 | 83.3 | 19 |
| Mississippi | 28 | 28 | 100.0 | 23 |
| North Carolina | 41 | 41 | 100.0 | 29 |
| South Carolina | 29 | 29 | 100.0 | 24 |
| Tennessee | 30 | 29 | 96.6 | 28 |
| REGION V | 579 | 579 | 100.0 | 321 |
| Illinois | 144 | 144 | 100.0 | 68 |
| Indiana | 57 | 57 | 100.0 | 42 |
| Michigan | 135 | 135 | 100.0 | 59 |
| Minnesota | 45 | 45 | 100.0 | 15 |
| Ohio | 153 | 153 | 100.0 | 106 |
| Wisconsin | 45 | 45 | 100.0 | 31 |
| REGION VI | 239 | 214 | 89.5 | 174 |
| Arkansas | 23 | 21 | 91.3 | 19 |
| Louisiana | 32 | 28 | 87.5 | 23 |
| New Mexico | 15 | 14 | 93.3 | 13 |
| Oklahoma | 29 | 28 | 96.5 | 25 |
| Texas | 140 | 123 | 87.8 | 94 |
| REGION VII | 105 | 84 | 80.0 | 57 |
| Iowa | 25 | 19 | 76.0 | 14 |
| Kansas | 41 | 29 | 70.7 | 19 |
| Missouri | 27 | 24 | 88.8 | 15 |
| Nebraska | 12 | 12 | 100.0 | 9 |
| REGION VIII | 80 | 80 | 100.0 | 50 |
| Colorado | 27 | 27 | 100.0 | 17 |
| Montana | 10 | 10 | 100.0 | 8 |
| North Dakota | 9 | 9 | 100.0 | 8 |
| South Dakota | 8 | 8 | 100.0 | 6 |
| Utah | 21 | 21 | 100.0 | 10 |
| Wyoming | 5 | 5 | 100.0 | 1 |
| REGION IX | 193 | 175 | 90.6 | 126 |
| Arizona | 4 | 4 | 100.0 | 4 |
| California | 174 | 156 | 89.6 | 107 |
| Hawaii | 8 | 8 | 100.0 | 8 |
| Nevada | 6 | 6 | 100.0 | 6 |
| American Samoa | -- | -- | -- | -- |
| Tr.Terr.of Pac.Islds. | -- | -- | -- | -- |
| Wake Island | 1 | 1 | 100.0 | 1 |
| REGION X | 95 | 93 | 97.8 | 69 |
| Alaska | 2 | 2 | 100.0 | 2 |
| Idaho | 11 | 11 | 100.0 | 10 |
| Oregon | 34 | 34 | 100.0 | 26 |
| Washington | 48 | 46 | 95.8 | 31 |

# TABLE 2

## ESTIMATED COST OF CONSTRUCTION OF PLANNED MUNICIPAL WASTE TREATMENT FACILITIES FOR MUNICIPALITIES WITH OR SERVING POPULATIONS OF 10,000 OR MORE, FOR PERIOD FY 1972-1976, BASED ON SURVEY COMPLETED IN DECEMBER 1971.

| | |
|---|---|
| TOTALS | 14,014.5 |
| Alabama | 68.1 |
| Alaska | 12.3 |
| Arizona | 14.0 |
| Arkansas | 49.8 |
| California | 1,743.2 |
| Colorado | 62.3 |
| Connecticut | 148.9 |
| Delaware | 48.9 |
| Dist. of Columbia | 108.7 |
| Florida | 556.8 |
| Georgia | 106.5 |
| Hawaii | 60.7 |
| Idaho | 23.4 |
| Illinois | 1,113.0 |
| Indiana | 476.7 |
| Iowa | 173.0 |
| Kansas | 44.9 |
| Kentucky | 115.6 |
| Louisiana | 89.8 |
| Maine | 62.3 |
| Maryland | 668.3 |
| Massachusetts | 495.6 |
| Michigan | 1,166.1 |
| Minnesota | 260.4 |
| Mississippi | 31.7 |
| Missouri | 255.2 |
| Montana | 22.2 |
| Nebraska | 88.4 |
| Nevada | 40.9 |
| New Hampshire | 89.7 |
| New Jersey | 1,249.6 |
| New Mexico | 18.5 |
| New York | 1,272.8 |
| North Carolina | 101.9 |
| North Dakota | 4.1 |
| Ohio | 909.6 |
| Oklahoma | 86.3 |
| Oregon | 120.0 |
| Pennsylvania | 516.7 |
| Rhode Island | 36.2 |
| South Carolina | 98.1 |
| South Dakota | 6.6 |
| Tennessee | 158.9 |
| Texas | 389.8 |
| Utah | 26.0 |
| Vermont | 0 |
| Virginia | 308.9 |
| Washington | 153.4 |
| West Virginia | 34.0 |
| Wisconsin | 176.5 |
| Wyoming | .9 |
| Guam | 3.0 |
| Puerto Rico | 145.3 |
| Virgin Islands | 0 |

December 1971

## TABLE 3

### SURVEY RESULTS OF ESTIMATED CONSTRUCTION COST OF SEWAGE TREATMENT FACILITIES PLANNED FOR THE PERIOD FY 1972-1976

(Millions of 1971 Dollars)

| | FY-1972 | FY-1973[1] | FY-1974[1] | FY-1975 | FY-1976 | Total |
|---|---|---|---|---|---|---|
| TOTALS | 5,278.2 | 6,080.0 | 3,198.2 | 2,236.5 | 1,289.3 | 18,082.2 |
| Alabama | 33.5 | 9.6 | 9.5 | 7.9 | 5.1 | 65.6 |
| Alaska | 4.1 | 26.4 | 2.3 | 7.5 | -- | 40.3 |
| Arizona | 10.7 | 8.9 | -- | 6.2 | 1.4 | 27.2 |
| Arkansas | 12.5 | 27.7 | 11.3 | 10.0 | -- | 61.5 |
| California | 280.4 | 930.9 | 218.4 | 369.0 | 340.8 | 2,139.5 |
| Colorado | 23.3 | 14.4 | 8.4 | 30.0 | 6.1 | 82.2 |
| Connecticut | 96.2 | 95.1 | 53.5 | -- | -- | 244.8 |
| Delaware | 7.8 | 8.8 | 79.0 | 2.5 | 5.6 | 103.7 |
| Dist. of Columbia | 62.7 | 40.9 | -- | -- | -- | 103.6 |
| Florida | 313.0 | 125.7 | 89.4 | 106.3 | 17.0 | 651.4 |
| Georgia | 36.3 | 89.6 | 15.8 | -- | 12.6 | 154.3 |
| Hawaii | 15.0 | 28.5 | 4.6 | 24.1 | -- | 72.2 |
| Idaho | 15.7 | 8.6 | 7.4 | .3 | .4 | 32.4 |
| Illinois | 336.7 | 332.5 | 240.8 | 382.9 | 38.7 | 1,331.6 |
| Indiana | 161.3 | 207.2 | 121.7 | 22.1 | 27.6 | 539.9 |
| Iowa | 16.8 | 78.8 | 72.7 | 21.8 | 7.2 | 197.3 |
| Kansas | 19.8 | 28.8 | 5.9 | 3.2 | 11.6 | 69.3 |
| Kentucky | 46.8 | 35.0 | 14.3 | 39.5 | 27.1 | 162.7 |
| Louisiana | 68.5 | 40.6 | 28.2 | 17.7 | .1 | 155.1 |
| Maine | 25.4 | 100.5 | 15.0 | 35.4 | 25.0 | 201.3 |
| Maryland | 201.5 | 204.0 | 214.6 | 15.7 | 36.6 | 672.4 |
| Massachusetts | 206.5 | 190.8 | 149.9 | 80.0 | -- | 627.2 |
| Michigan | 331.8 | 523.2 | 307.3 | 100.4 | 130.0 | 1,392.7 |
| Minnesota | 142.3 | 112.1 | 41.5 | 30.8 | 12.9 | 339.6 |
| Mississippi | 32.5 | 17.4 | 7.4 | 14.5 | 18.2 | 90.0 |
| Missouri | 9.2 | 160.0 | 71.9 | 38.1 | 27.4 | 306.6 |
| Montana | 13.7 | 2.7 | 7.8 | -- | 3.0 | 27.2 |
| Nebraska | 1.8 | 28.7 | 23.5 | 24.1 | 15.7 | 93.8 |
| Nevada | .4 | 30.7 | 10.8 | 1.3 | -- | 43.2 |
| New Hampshire | 21.3 | 36.9 | 62.8 | 58.5 | 10.5 | 190.0 |
| New Jersey | 461.9 | 554.4 | 105.6 | 299.6 | 6.3 | 1,427.8 |
| New Mexico | 17.8 | 12.8 | .1 | -- | -- | 30.7 |
| New York | 1,047.1 | 422.4 | 140.8 | 102.0 | 167.2 | 1,879.5 |
| North Carolina | 36.6 | 66.5 | 31.3 | 18.2 | 1.1 | 153.7 |
| North Dakota | 1.4 | 3.7 | 1.7 | -- | .3 | 7.1 |
| Ohio | 277.2 | 250.3 | 313.3 | 62.7 | 156.8 | 1,060.3 |
| Oklahoma | 14.4 | 24.2 | 28.5 | 8.1 | 39.8 | 115.0 |
| Oregon | 41.5 | 72.3 | 9.9 | 13.0 | 12.6 | 149.3 |
| Pennsylvania | 187.2 | 343.3 | 259.0 | 105.8 | 1.2 | 896.5 |
| Rhode Island | 9.9 | 35.6 | 25.7 | -- | -- | 71.2 |
| South Carolina | 31.2 | 29.5 | 33.3 | 18.8 | 17.8 | 130.6 |
| South Dakota | 9.3 | 1.7 | 2.8 | 3.3 | .9 | 18.0 |
| Tennessee | 120.6 | 31.0 | 17.4 | 11.9 | 7.8 | 188.7 |
| Texas | 127.5 | 165.5 | 110.3 | 34.4 | 11.5 | 449.2 |
| Utah | 14.5 | 3.5 | 2.5 | 1.4 | 5.5 | 27.4 |
| Vermont | 5.3 | 13.5 | 13.5 | 6.3 | 3.7 | 42.3 |
| Virginia | 100.0 | 243.3 | 81.1 | 11.0 | 61.5 | 496.9 |
| Washington | 38.1 | 67.8 | 23.8 | 52.6 | 5.8 | 188.1 |
| West Virginia | 38.2 | 32.5 | 2.1 | 23.0 | -- | 95.8 |
| Wisconsin | 135.1 | 97.2 | 21.3 | 6.6 | 3.9 | 264.1 |
| Wyoming | 1.5 | 2.4 | -- | -- | -- | 3.9 |
| Guam | 2.2 | 10.5 | -- | 4.1 | .7 | 17.5 |
| Puerto Rico | 4.2 | 48.6 | 76.0 | .8 | .5 | 130.1 |
| Virgin Islands | 8.0 | 2.5 | 2.5 | 3.1 | 3.8 | 19.9 |

[1] Separate costs for FY 1973 and FY 1974 estimated from FY 1972/1974 total.

# PLANNED INVESTMENT AS DERIVED FROM THE MUNICIPAL WASTE TREATMENT FACILITIES EVALUATION MODEL

## Introduction

This section reports the results of the Waste Treatment Facilities Evaluation model as applied to the current (1971) Municipal Waste Inventory. The model calculates the value of recognized improvement needs (backlog) and the replacement value of capital in place. This part briefly states how the model is constructed. A full explanation can be found in The Economics of Clean Water, Volume I, 1970.

The results of the model are then used in an investment scheduling procedure which calculates the level of investment required to obtain the level of treatment of public wastes that have been determined by the States to match in general water quality objectives. Finally, the various elements of the investment requirements are also compared to the results obtained in 1969 when a similar model evaluated capital values and investment needs for 1968.

## Waste Treatment Facilities Evaluation Model

This model is a mathematical simulation of investment in public waste handling systems. The model facilitates the calculation of the value of recognized improvements needed in the treatment or operation of waste treatment systems as stated in the Municipal Waste Inventory. It is designed to answer questions regarding the current amount of recognized waste treatment needs or backlog.

The model correlates a series of equations that define size (as per capita design flow) to cost (in constant 1957-59 dollars) relationships for basic waste-handling procedures and equipment. Such cost functions are found in papers by Robert Michel[1] and Robert Smith.[2] The model scans the Municipal Waste Inventory for any needs recorded. All community and/or municipal waste facilities are entered into the inventory where either: (a) an operational facility, with or without additional abatement needs, is in place; or (b) the need for a facility has been identified where none now exists. (Excluded are unsewered communities and dwellings.)

The model calculates the average cost of installing or constructing the particular facilities--sized according to a normal statistical distribution of capacity to indicated load for existing plants in the same State. The costs are stated in terms of constant dollars. (Sewer and Sewage Treatment Plant Construction Cost Indices, supplied by EPA, may be applied to modify price levels.) This procedure supplies the value of recognized improvements needed in waste treatment or operation of waste treatment systems.

The second part of this modeling technique is a calculation of the current replacement value of facilities in place. The current replacement value was calculated on the basis of costs experienced in building facilities with similar design flow and removal efficiencies.

Table 4 presents these two values calculated for each State and compares the figures with a similar calculation done in 1969. The figures are in September 1969 dollars and June 1971 dollars. The figures for 1969 inflated to June 1971 prices by the Sewage Treatment Cost Index are also indicated.

The differences in existing facilities nationally between the years 1968 and 1971 are presented in Table 5 and are reflected in the two figures for the value of capital in place ($12,392.0 and $18,875.0 million in current dollars and $9,421.7 and $11,636.5 million in constant 1957-59 dollars).

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[1] Construction Cost of Municipal Wastewater Plants (1967-1969), September, 1969.

[2] Cost of Conventional and Avanced Treatment of Wastewaters, 1968.

## TABLE 4

## EVALUATION OF CAPITAL IN PLACE AND OF DEFINED NEEDS

| | Value of Works in Place ($000,000) | | Value of Needed Works | |
|---|---|---|---|---|
| | 1968 | 1971 | 1968 | 1971 |
| Alabama | 191.8 | 224.1 | 122.8 | 77.3 |
| Alaska | 1.5 | 5.0 | 8.3 | 22.0 |
| Arizona | 62.9 | 99.9 | 20.4 | 31.0 |
| Arkansas | 147.7 | 183.7 | 44.6 | 17.0 |
| California | 1061.4 | 2060.7 | 377.2 | 530.3 |
| Colorado | 228.9 | 428.9 | 43.2 | 58.6 |
| Connecticut | 128.8 | 181.3 | 73.4 | 2.7 |
| Delaware | 34.5 | 19.0 | 3.5 | 3.5 |
| Dist. of Columbia | 46.4 | 525.1 | 28.2 | 4.0 |
| Florida | 431.1 | 456.3 | 48.4 | 238.8 |
| Georgia | 281.8 | 303.9 | 123.8 | 201.4 |
| Hawaii | 23.2 | 26.1 | 25.9 | 25.0 |
| Idaho | 80.0 | 159.4 | 33.5 | 14.5 |
| Illinois | 686.1 | 921.3 | 194.9 | 78.5 |
| Indiana | 431.9 | 999.9 | 139.2 | 151.4 |
| Iowa | 285.9 | 305.5 | 44.3 | 34.4 |
| Kansas | 254.6 | 318.3 | 82.5 | 64.7 |
| Kentucky | 193.9 | 267.2 | 16.3 | 28.1 |
| Louisiana | 193.3 | 166.6 | 79.2 | 41.3 |
| Maine | 24.7 | 26.6 | 91.8 | 30.2 |
| Maryland | 121.9 | 478.2 | 28.3 | 57.8 |
| Massachusetts | 141.0 | 195.4 | 209.2 | 50.6 |
| Michigan | 348.2 | 626.5 | 135.7 | 371.5 |
| Minnesota | 283.2 | 415.9 | 54.4 | 155.8 |
| Mississippi | 151.7 | 149.9 | 50.0 | 44.6 |
| Missouri | 316.0 | 335.0 | 148.8 | 87.5 |
| Montana | 75.5 | 76.4 | 22.6 | 18.6 |
| Nebraska | 171.1 | 194.3 | 38.2 | 15.2 |
| Nevada | 40.8 | 76.4 | 17.0 | 5.1 |
| New Hampshire | 22.5 | 23.7 | 61.5 | 10.8 |
| New Jersey | 420.1 | 379.7 | 162.0 | 54.3 |
| New Mexico | 98.8 | 119.9 | 10.2 | 24.4 |
| New York | 801.0 | 1015.2 | 276.0 | 578.6 |
| North Carolina | 342.7 | 401.7 | 101.7 | 73.5 |
| North Dakota | 77.8 | 76.4 | 6.6 | 14.8 |
| Ohio | 668.9 | 1205.2 | 229.9 | 296.2 |
| Oklahoma | 236.9 | 332.1 | 31.7 | 33.5 |
| Oregon | 171.7 | 328.9 | 64.2 | 36.2 |
| Pennsylvania | 585.4 | 789.5 | 362.3 | 231.3 |
| Rhode Island | 52.6 | 82.8 | 22.9 | 9.8 |
| South Carolina | 156.1 | 161.7 | 66.9 | 59.4 |
| South Dakota | 81.0 | 72.9 | 13.8 | .4 |
| Tennessee | 232.5 | 328.6 | 71.8 | 79.6 |
| Texas | 882.0 | 1440.7 | 161.5 | 459.2 |
| Utah | 120.8 | 191.5 | 28.0 | 41.5 |
| Vermont | 28.7 | 32.3 | 40.8 | 13.0 |
| Virginia | 229.4 | 309.6 | 65.6 | 147.7 |
| Washington | 197.6 | 448.4 | 90.1 | 98.7 |
| West Virginia | 102.0 | 157.2 | 74.9 | 31.5 |
| Wisconsin | 350.9 | 628.2 | 124.5 | 187.5 |
| Wyoming | 52.7 | 53.2 | 8.8 | 4.4 |
| Guam | 0. | 0. | 0. | 0. |
| Puerto Rico | 47.1 | 68.5 | 32.6 | 132.8 |
| Virgin Islands | 0. | 0. | 3.7 | 0. |
| TOTAL | 12392.0 | 18874.5 | 4417.5 | 5080.5 |
| TOTAL | 15316.5[1] | 18874.5 | 5460.0[1] | 5080.5 |

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[1] 1971 Dollars.

## TABLE 5

## PATTERN OF EXISTING FACILITIES

| Number of Plants Per Treatment Level | 1968 | 1971 | Percent of Total Plants | 1969 | 1971 |
|---|---|---|---|---|---|
| Primary | 2384 | 2119 | | 19.1 | 17.0 |
| Intermediate | 75 | 8 | | .6 | 0.2 |
| Secondary | 9951 | 10,154 | | 80.2 | 82.2 |
| Tertiary | 10 | 100 | | .1 | 0.8 |
| TOTAL | 12,420 | 12,381 | | 100.0 | 100.0 |

| Construction Cost Per mgd of Capacity | Current Dollars | |
|---|---|---|
| | 1969 | 1971 |
| Primary | 380,700 | 476,471 |
| Intermediate | 380,700 | 682,033 |
| Secondary | 654,480 | 748,740 |
| Tertiary | 1,308,960 | 925,713 |

## Elements of the Investment Requirement

Table 6 summarizes the computed value associated with the various categories of investment needs, as these were listed in the (1971) Municipal Waste Inventory and assessed by the evaluation model.

The various categories are:

| | |
|---|---|
| New Plants: | preliminary treatment, primary, secondary, tertiary, and lagoons. |
| Upgrading: | same as for new plants while treatment level is the one achieved, i.e. treatment level changes. |
| Other Improvements: | modification of existing treatment; addition of nutrient removal processes; addition of color, odor, or taste removal processes; deep ocean outfalls. |

The largest categories of investment needs are for upgrading the level of existing treatment and enlargement of an existing plant. Together they constitute $3443.73 million of the total backlog value and about 3100 individual projects.

A comparison of these figures with those obtained in 1969 (cf. Table 6) shows that there has been a shift away from a need for new plants. Whereas in 1969, 40.2 percent of the backlog value was found in costs of building new plants and 54.3 percent for upgrading or enlarging existing facilities, the recent calculations for 1971 show only 5.1 percent for new plants and an increase to 67.7 percent for upgrading or enlargement. The other three categories have also increased as a percentage of the total.

The actual number of different recognized improvement needs in the categories of Table 6 has decreased while the number of systems expressing those needs has increased from 13,849 in 1968 to 15,012 in 1971. This information is presented in Table 7 along with comparisons of population served by those communities having needs over time.

## Alternative Investment Schedules

For the immediate future the evaluation model can determine the level of investment required nationally to obtain the level of public waste treatment which is needed to meet general water quality objectives.

The approximate rate at which investment requirements are accumulating and the amount of the current accumulation of need are known. Thus,

## TABLE 6

## COMPUTED VALUES FOR VARIOUS CATEGORIES OF NEEDS OVER TIME

(millions of current dollars)

| Need | 1969 | Percent Of Total | 1971 | Percent Of Total |
|---|---|---|---|---|
| New Plants | 1775.00 | 40.2 | 257.66 | 5.1 |
| Upgrading | 1332.62 | 30.2 | 1745.67 | 34.3 |
| Enlargement | 1067.50 | 24.1 | 1698.06 | 33.4 |
| Disinfection | 27.68 | 0.6 | 467.37 | 9.2 |
| Connection to An Existing System | 198.28 | 4.5 | 396.48 | 7.8 |
| Other Improvements | 16.01 | 0.3 | 515.80 | 10.1 |
| TOTAL | 4417.55 | 100.0 | 5081.04 | 100.0 |

TABLE 7

INCREASE IN DEFINED WASTE TREATMENT NEEDS OVER TIME

| Kind of Need | Number of Systems |  |  |  | Population Served (000's) |  |  |  |
|---|---|---|---|---|---|---|---|---|
|  | 1957 | 1962 | 1968 | 1971 | 1957 | 1962 | 1968 | 1971 |
| New Facilities[1] | 3579 | 3311 | 2334 | 2821 |  |  |  |  |
| Major Upgrading[2] | 1441 | 3071 | 3133 | 2564 |  |  |  |  |
| Minor Upgrading[3] | 370 | 374 | 932 | 297 |  |  |  |  |
| Total No. Needs | 5,390 | 5,045 | 6,399 | 5,682 | 41,770.3 | 51,763.3 | 80,330.6 | 55,262.3 |
| Total Systems | 10,511 | 11,006 | 13,849 | 15,012 | 98,361.9 | 118,371.9 | 139,726.7 | 176,658.9 |
| Percent With Needs | 51.3 | 45.8 | 46.2 | 37.8 | 42.5 | 43.7 | 57.5 | 31.2 |

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[1] New Plant, replacement, connection
[2] Enlargement, additional treatment
[3] Chlorination, modification

a projection procedure is utilized to find the annual rate of investment that will sustain existing physical capital, meet expansion requirements, minimize price increases, and eliminate the accumulation of investment requirements that currently exists (backlog).

The procedure used takes into account both the existing capital stock and the following variables which constitute elements of the investment activity--i.e., growth, recapitalization, and the backlog of accumulated demands. The procedure also assumes a constant rate of inflation in construction costs and a constant rate of growth.

Recapitalization, capital in place, and backlog are derivatives of investment. Recapitalization is calculated as 2.9 percent of capital in place in any year. Growth needs are calculated to amount in any year to 3.3 percent of capital in place. To the extent that the investment covered growth requirements, the value is transferred to capital in place. Values exceeding available investment are added to the backlog of unmet needs. The backlog itself is reduced by any amount that available investments exceed recapitalization and growth elements, or increased as prior demands on a hypothesized investment exceed the amount of available investment.

### Investment Schedules

Using the figures for value of backlog as $5081 million and for value of capital in place as $18,875 million obtained from the evaluation model, this procedure indicates that a $2870.9 million annual outlay is required to reduce accumulated needs within a five-year period in which inflation compounds at 7.5 percent annually.

The 1970 rate of inflation in the construction sector was 15 percent; however, administration efforts to control inflation should bring the rate of price increases in this sector nearer to the historical rate for 1968-1971, which is approximately 7.5 percent and would give the following investment schedule:

FIVE-YEAR BACKLOG ELIMINATION SCHEDULE AT 7.5 PERCENT INFLATION

| Year | "Backlog" At Year End | Growth | Recapitalization | Investment |
|---|---|---|---|---|
| 1971 | 5081.0 | | | |
| 1972 | 3871.2 | 691.7 | 588.4 | 2870.9 |
| 1973 | 2740.9 | 768.1 | 682.2 | 2870.9 |
| 1974 | 1706.1 | 853.0 | 777.6 | 2870.9 |
| 1975 | 784.9 | 947.2 | 874.6 | 2870.9 |
| 1976 | 0.0 | 1051.8 | 972.9 | 2870.9 |

| | |
|---|---|
| Total Investment, 1972-1976 | 14,354.5 |
| "Backlog" | 6,147.0 |
| Growth | 4,311.8 |
| Recapitalization | 3,895.7 |

Thus the investment scheduling procedure shows that if this inflation is held down, the total amount of the investment required to eliminate accumulated needs within the next five years would be $14.3 billion. The breakdown by State is shown in Table 8.

## TABLE 8

### MODEL INVESTMENT SCHEDULE
### INVESTMENT NEEDED TO REDUCE BACKLOG BY 1976

(Millions of 1971 Dollars)

| | |
|---|---|
| TOTALS | 14,354.5 |
| Alabama | 201.0 |
| Alaska | 28.7 |
| Arizona | 86.1 |
| Arkansas | 100.5 |
| California | 1,550.3 |
| Colorado | 258.4 |
| Connecticut | 71.8 |
| Delaware | 14.4 |
| Dist. of Columbia | 215.3 |
| Florida | 502.4 |
| Georgia | 387.6 |
| Hawaii | 43.1 |
| Idaho | 86.1 |
| Illinois | 488.1 |
| Indiana | 617.2 |
| Iowa | 172.3 |
| Kansas | 215.3 |
| Kentucky | 143.5 |
| Louisiana | 129.2 |
| Maine | 43.1 |
| Maryland | 272.7 |
| Massachusetts | 143.5 |
| Michigan | 760.8 |
| Minnesota | 373.2 |
| Mississippi | 114.8 |
| Missouri | 258.4 |
| Montana | 57.4 |
| Nebraska | 100.5 |
| Nevada | 43.1 |
| New Hampshire | 28.7 |
| New Jersey | 229.7 |
| New Mexico | 86.1 |
| New York | 1,004.8 |
| North Carolina | 258.4 |
| North Dakota | 57.4 |
| Ohio | 890.0 |
| Oklahoma | 186.6 |
| Oregon | 186.6 |
| Pennsylvania | 631.6 |
| Rhode Island | 43.1 |
| South Carolina | 143.5 |
| South Dakota | 28.7 |
| Tennessee | 244.0 |
| Texas | 1,205.8 |
| Utah | 129.2 |
| Vermont | 28.7 |
| Virginia | 330.1 |
| Washington | 315.8 |
| West Virginia | 114.8 |
| Wisconsin | 502.4 |
| Wyoming | 28.7 |
| Guam | |
| Puerto Rico | 201.0 |
| Virgin Islands | |

## COMPARISON OF THE 1970 AND THE 1971 ESTIMATES OF PLANNED CONSTRUCTION ACTIVITY

### Comparison of Surveys

The 1970's survey projected an estimate of $12.6 billion for planned construction activity (cf. Table 9) in the municipal waste treatment area. The period covered in the 1970 survey was from December, 1970 through June, 1974, a total of 43 months. Four hundred and fifty municipalities were chosen on the basis of having projects of $5 million or more. The remaining communities were covered by reviewing State program plants.

The 1971 survey results project an estimate of $18.1 billion. The difference between the $12.6 billion estimate in 1970 and the $18.1 billion estimate in 1971 comes from various sources. Some of the more pertinent are:

1. The time period in the most recent survey is longer, FY 1972 through FY 1976 or a total of 60 months versus 43 months in in the earlier summary.

2. The 15 percent inflation rate in the cost of construction in the period between the two surveys.

3. The planned projects were formulated by municipalities to meet water quality standards, which in certain situations may have become more stringent.

4. The increasing availability of up-to-date engineering estimates for projects previously assessed in their rudimentary planning stages. For example, a project which went under construction in New York City earlier in 1971 was estimated by the designers to cost about $100 million. The lowest bid received on the project was about $229 million. Experiences such as these have prompted many communities to update their cost estimates.

5. More comprehensive assessing and reporting; 2300 communities in 1971 as opposed to 450 in 1970.

6. Acceleration of construction schedules. The State of California has advised its communities that the State's Clean Water Grant Program is for a five-year period only. All required pollution control facilities are to be initiated prior to the termination of the program or they will not receive State assistance. This required the San Francisco Bay Area, for example, to condense its thirty-year program into five.

7. The necessity of municipalities meeting water quality standards and related implementation plans within the next five years. The enforcement of these requirements is undoubtedly a factor in the shaping of imminent needs and their associated costs.

## TABLE 9

## ESTIMATED COST OF CONSTRUCTION OF MUNICIPAL SEWAGE TREATMENT WORKS FOR THE PERIOD DECEMBER 1970 THROUGH JUNE 1974

($ MILLION)

| | |
|---|---|
| TOTALS | $ 12,565.2 |
| Alabama | 27.0 |
| Alaska | 28.1 |
| Arizona | 51.0 |
| Arkansas | 42.0 |
| California | 737.5 |
| Colorado | 47.4 |
| Connecticut | 229.5 |
| Delaware | 62.0 |
| Dist.of Columbia | 347.2 |
| Florida | 444.2 |
| Georgia | 74.0 |
| Hawaii | 50.8 |
| Idaho | 14.5 |
| Illinois | 1,043.6 |
| Indiana | 174.8 |
| Iowa | 111.9 |
| Kansas | 52.7 |
| Kentucky | 117.0 |
| Louisiana | 132.7 |
| Maine | 157.4 |
| Maryland | 349.7 |
| Massachusetts | 422.6 |
| Michigan | 788.8 |
| Minnesota | 295.2 |
| Mississippi | 34.1 |
| Missouri | 268.2 |
| Montana | 31.4 |
| Nebraska | 49.0 |
| Nevada | 47.2 |
| New Hampshire | 137.8 |
| New Jersey | 1,308.7 |
| New Mexico | 19.6 |
| New York | 1,721.0 |
| North Carolina | 125.3 |
| North Dakota | 8.4 |
| Ohio | 733.5 |
| Oklahoma | 69.8 |
| Oregon | 78.6 |
| Pennsylvania | 616.4 |
| Rhode Island | 37.7 |
| South Carolina | 57.6 |
| South Dakota | 13.5 |
| Tennessee | 88.9 |
| Texas | 398.7 |
| Utah | 22.6 |
| Vermont | 38.0 |
| Virginia | 280.1 |
| Washington | 216.3 |
| West Virginia | 51.4 |
| Wisconsin | 190.8 |
| Wyoming | 1.7 |
| Guam | 9.7 |
| Puerto Rico | 93.0 |
| Virgin Islands | 14.6 |

December 1970

8. The rise in the number of tertiary treatment facilities required to meet water quality standards.

In the past ten years the surveys which were done to assess "needs" have no consistent definition of their objective[3] so that a historical comparison of such "needs" estimates is impossible. A comparison of estimates that take total investment into account are even more disparate. In the past three years the "needs" estimate has risen from $10.2 billion to $18.1 billion. Adding the latest survey estimate and the amount of projects funded ($6.3 billion) in the period between the two surveys gives $24.4 or a 139 percent increase in these three years (cf. Table 10).

## Comparison of the Model with Survey Results

The evaluation model results in an estimate of $14.3 billion needed to be invested during the period FY 1972-1976 in order to overcome deficiencies in present facilities and to keep pace with growth, capital replacement, and inflation. On the other hand, the survey result of $18.1 billion is an aggregation of State and local estimates of their construction activity during this same period. The basic differences between the model approach and the survey approach will be discussed. This will be followed by an *ex post* evaluation of model projections, which compares model projections with actual investment activity. Finally, the projections of the model and the survey will be evaluated in light of potential construction activity during the FY 1972-1976 period.

### Difference Between Model and Survey Approaches

There are several basic methodological differences between the survey and the model:

1. The model uses statistically derived cost function to calculate the cost of planned construction activity, whereas the survey

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[3] In 1962 the *Conference of State Sanitary Engineers* report said $2 billion was needed to "eliminate the backlog of unmet waste treatment 'needs'". In 1966, the JEC *State and Local Public Facility Needs and Financing* report, also from State Conference, stated $2.6 billion in "needs". In 1969, the FWQA survey of State governments produced $10.02 billion. In 1970, an EPA survey of State governments and communities indicated a total investment need of $12.6 billion. In 1971, the same EPA survey reported for communities of served population of 10,000 or more $14.0 billion or, including all communities, the total "needs" reach $18.1 billion. Again in 1970, the American League of Cities survey reported over $30 billion in "needs", although the municipalities in this case did not use consistent reporting requirements and some included costs of facilities other than for waste treatment needs.

## TABLE 10

## CHANGES IN STATE SEWAGE TREATMENT INVESTMENT NEEDS EXPRESSED, 1969-1971 ($ MILLIONS)

| | Needs Expressed 1969 | Projects Funded Jan. 1, 1969 to Oct. 31, 1971 | Needs Expressed Nov. 1971 | Gross Change In Needs | Percent Change Over 1969 |
|---|---|---|---|---|---|
| TOTALS | 10,217.1 | 6,329.4 | 18,083.0 | +14,195.3 | + 138.9 |
| Alabama | 35.0 | 67.9 | 65.7 | + 98.6 | + 281.7 |
| Alaska | 12.0 | 14.8 | 40.3 | + 43.1 | + 359.2 |
| Arizona | 86.0 | 11.1 | 27.2 | - 47.7 | - 55.5 |
| Arkansas | 33.0 | 18.7 | 61.5 | + 47.2 | + 143.0 |
| California | 651.8 | 309.4 | 2,139.5 | + 1,797.1 | + 275.7 |
| Colorado | 133.0 | 49.2 | 82.2 | - 1.6 | - 1.2 |
| Connecticut | 280.5 | 232.6 | 244.8 | + 196.9 | + 70.2 |
| Delaware | 28.0 | 32.1 | 103.7 | + 107.8 | + 385.0 |
| Dist. of Columbia | 355.0 | 78.6 | 103.6 | 172.8 | - 48.6 |
| Florida | 200.0 | 180.3 | 651.4 | + 651.4 | + 315.9 |
| Georgia | 150.0 | 199.4 | 154.3 | + 203.7 | + 135.8 |
| Hawaii | 14.4 | 11.8 | 72.2 | + 69.6 | + 483.3 |
| Idaho | 0.5 | 10.6 | 77.4 | + 42.5 | +8,500.0 |
| Illinois | 437.2 | 261.9 | 1,331.5 | + 1,156.2 | + 264.5 |
| Indiana | 152.6 | 87.9 | 538.8 | + 470.1 | + 308.1 |
| Iowa | 33.3 | 53.3 | 197.3 | + 217.3 | + 652.6 |
| Kansas | 61.0 | 60.8 | 69.3 | + 69.1 | + 113.3 |
| Kentucky | 62.6 | 98.5 | 162.8 | + 198.7 | + 317.4 |
| Louisiana | 140.0 | 61.2 | 155.0 | + 76.2 | + 54.4 |
| Maine | 140.9 | 47.2 | 201.3 | + 107.6 | + 76.4 |
| Maryland | 236.9 | 163.4 | 672.4 | + 598.9 | + 252.8 |
| Massachusetts | 438.0 | 94.3 | 627.2 | + 283.5 | + 64.7 |
| Michigan | 253.7 | 465.4 | 1,392.6 | + 1,604.3 | + 632.4 |
| Minnesota | 136.3 | 99.7 | 339.6 | + 303.0 | + 222.3 |
| Mississippi | 40.0 | 41.0 | 90.0 | + 91.0 | + 227.5 |
| Missouri | 390.0 | 80.4 | 306.5 | - 3.1 | - 0.8 |
| Montana | 13.5 | 14.9 | 27.3 | + 28.7 | + 212.6 |
| Nebraska | 62.0 | 28.8 | 93.9 | + 60.7 | + 97.9 |
| Nevada | 28.6 | 19.9 | 43.1 | + 34.4 | + 120.3 |
| New Hampshire | 138.0 | 46.4 | 190.0 | + 98.4 | + 71.3 |
| New Jersey | 880.0 | 208.8 | 1,427.9 | + 756.7 | + 85.3 |
| New Mexico | 9.9 | 14.4 | 30.8 | + 38.3 | + 35.3 |
| New York | 1,900.1 | 1,512.7 | 1,879.6 | + 1,492.2 | + 78.5 |
| North Carolina | 69.3 | 110.9 | 153.7 | + 195.3 | + 281.8 |
| North Dakota | 22.0 | 4.5 | 7.1 | - 10.4 | - 47.3 |
| Ohio | 432.5 | 347.3 | 1,060.4 | + 975.2 | + 225.5 |
| Oklahoma | 65.3 | 74.6 | 115.0 | + 124.3 | + 190.4 |
| Oregon | 135.0 | 64.2 | 149.2 | + 78.4 | + 58.1 |
| Pennsylvania | 432.0 | 237.6 | 896.5 | + 702.1 | + 162.5 |
| Rhode Island | 51.5 | 11.0 | 71.2 | + 30.7 | + 59.6 |
| South Carolina | 75.0 | 49.1 | 130.6 | + 104.7 | + 139.6 |
| South Dakota | 27.0 | 3.0 | 18.1 | - 5.9 | - 21.9 |
| Tennessee | 105.5 | 89.9 | 188.7 | + 173.1 | + 164.1 |
| Texas | 525.0 | 200.1 | 449.3 | + 124.4 | + 23.7 |
| Utah | 11.7 | 5.2 | 27.4 | + 20.9 | + 178.6 |
| Vermont | 70.0 | 15.4 | 42.3 | - 12.3 | - 17.6 |
| Virginia | 151.0 | 107.8 | 497.4 | + 454.2 | + 300.8 |
| Washington | 160.0 | 101.0 | 188.1 | + 129.1 | + 80.7 |
| West Virginia | 44.3 | 10.8 | 95.8 | + 62.3 | + 140.6 |
| Wisconsin | 243.7 | 160.7 | 264.1 | + 181.1 | + 74.3 |
| Wyoming | 12.0 | 1.8 | 3.9 | - 6.3 | - 52.5 |
| Guam | 6.2 | 6.1 | 17.5 | + 17.4 | + 280.6 |
| Puerto Rico | 28.9 | 52.7 | 130.1 | + 153.9 | + 532.5 |
| Virgin Islands | 15.4 | 9.7 | 19.9 | + 14.2 | + 92.2 |

relies on individual communities' knowledge of the cost of planned facilities. In some communities well-documented and calculated cost information exist; however, this is not universally true.

2. The model uses statistically estimated growth and replacement factors, which determine the construction required to maintain the nation's capital stock of treatment plants and to provide treatment for additional population and industrial wastes. The growth projections obtained by the survey for an individual community are likely to be overly optimistic when compared to the growth of all communities. The replacement rate (depreciation) is difficult to assess for an individual community because of the lumpiness involved in replacement expenditures.

3. The model also includes a specific inflation factor which adjusts for price increases in construction activities. As noted in the survey discussion, State and local intentions are expressed in 1971 dollars.

A primary purpose of the survey is to give an indication of each local government's construction plans in the municipal waste treatment sector. The survey reflects the summation of local activities which, when viewed in the aggregate, presents an estimate of desired construction activity which may or may not commence during the period FY 1972-1976, e.g. compressing of the twenty-year California program into five years. The purpose of the model is slightly different in that it provides an estimate of the investment activity between 1972 and 1976 that local governments will be required to undertake in order to maintain their current growth and replacement needs and make progress toward constructing those facilities required to meet water quality standards.

## Historical Evaluation of Model Results

One way to assess the model results is to compare these results with actual past conditions in the municipal waste treatment facilities sector of economy.

The demand model based on physical capital and structured to reflect the dynamics of investment provided good post hoc agreement with actual conditions. The "needs" in 1969 were estimated at $3,201 million in constant dollars (1957-59 = 100). Assuming a growth rate of 3.3 percent in each year since then:

|  | Growth ($ millions) |
|---|---|
| 1969 | 416.5 |
| 1970 | 430.4 |
| 1971 | 444.5 |

and a replacement rate of existing plants of 3 percent:

| | Replacement ($ millions) |
|---|---|
| 1969 | 282.7 |
| 1970 | 292.0 |
| 1971 | 307.0 |

and subtracting those contracts awarded in each year:

| | Contracts ($ millions) |
|---|---|
| 1969 | 622.0 |
| 1970 | 766.2 |
| 1971 | 876.0 |

a "needs" reduction of $91.1 million and a projected 1971 "needs" of $3,110 million is obtained. This figure compares favorably with the value $3,132.2 million computed with the model. Also capital in place in 1968 was $9421.7 million (1957-59 dollars). This value is reduced by 3 percent annual replacement and increased by the value of contract awards in each subsequent year, which

| | Replacement ($ millions) | Investment |
|---|---|---|
| 1969 | 282.7 | 622.0 |
| 1970 | 292.0 | 766.2 |
| 1971 | 307.0 | 876.0 |

projects a 1971 capital in place value of $10,804.2 million, as compared to a computed value of $11,636.5 million.

In sum,this post hoc projection indicates divergence from "needs" within 1 percent and from capital in place within 8 percent, as compared to a greater than 130 variation percent for the survey.

## Construction Supply Capability

The question of the ability of the construction industry for municipal wastewater facilities to construct the planned investment activity must be considered in projecting the level of activity in this sector. The survey projected $5.28 billion of grant awards on FY 1972 and $18.1 for the five-year period FY 1972-1976, while the model on the other hand projected a need of $14.3 billion with an acreage of $2.8 billion contracted annually. Furthermore, there exists a backlog of $3.4 billion in grants that have been obligated but are not yet under construction (cf. Table 11), which must be included in an assessment of construction activity.

## TABLE 11

## VALUE OF PROJECTS PENDING CONSTRUCTION AND UNDER CONSTRUCTION AS OF OCTOBER 31, 1971

($ MILLIONS)

| | PENDING CONSTRUCTION | UNDER CONSTRUCTION |
|---|---|---|
| TOTALS | 3,400.3 | 4626.9 |
| Alabama | 74.5 | 36.2 |
| Alaska | 10.9 | 17.1 |
| Arizona | 5.5 | 12.3 |
| Arkansas | 14.6 | 19.1 |
| California | 117.1 | 229.0 |
| Colorado | 32.7 | 19.3 |
| Connecticut | 34.0 | 258.1 |
| Delaware | 24.7 | 16.7 |
| Dist. of Columbia | 77.8 | 24.4 |
| Florida | 50.9 | 137.3 |
| Georgia | 94.6 | 157.6 |
| Hawaii | 12.4 | 8.3 |
| Idaho | 13.1 | 1.5 |
| Illinois | 137.7 | 163.3 |
| Indiana | 60.4 | 32.0 |
| Iowa | 35.7 | 20.6 |
| Kansas | 46.8 | 13.8 |
| Kentucky | 45.1 | 80.7 |
| Louisiana | 58.9 | 32.8 |
| Maine | 25.3 | 34.6 |
| Maryland | 114.8 | 148.8 |
| Massachusetts | 29.6 | 100.8 |
| Michigan | 328.5 | 178.1 |
| Minnesota | 71.0 | 40.0 |
| Mississippi | 46.1 | 17.3 |
| Missouri | 40.7 | 108.8 |
| Montana | 14.1 | 2.3 |
| Nebraska | 19.5 | 15.9 |
| Nevada | 12.9 | 7.0 |
| New Hampshire | 12.5 | 45.4 |
| New Jersey | 79.9 | 155.8 |
| New Mexico | 10.8 | 5.3 |
| New York | 640.9 | 1408.3 |
| North Carolina | 72.9 | 50.4 |
| North Dakota | 3.5 | 1.3 |
| Ohio | 178.2 | 206.1 |
| Oklahoma | 61.7 | 32.0 |
| Oregon | 9.6 | 54.5 |
| Pennsylvania | 145.3 | 220.1 |
| Rhode Island | 2.5 | 23.8 |
| South Carolina | 28.4 | 64.6 |
| South Dakota | 1.6 | 2.2 |
| Tennessee | 26.8 | 80.3 |
| Texas | 140.7 | 94.8 |
| Utah | 2.5 | 5.3 |
| Vermont | 8.7 | 10.5 |
| Virginia | 73.1 | 75.7 |
| Washington | 64.7 | 48.8 |
| West Virginia | 28.5 | 4.0 |
| Wisconsin | 121.1 | 49.6 |
| Wyoming | 0.9 | 0.9 |
| Guam | 6.1 | 1.5 |
| Puerto Rico | 29.7 | 39.3 |
| Virgin Islands | 0.2 | 12.8 |

To place the projections of planned activity into perspective, the recent trends in construction activity, i.e. the lag in starts and completions, the ability of this sector of the construction industry to expand, and the inflation experienced in this sector will be discussed.

## Lags

Under present conditions it takes over five years, on the average, to complete a sewage project. The time lag between when a project is planned at the State or local level, when a federal grant is obligated, and when construction begins is widening. In 1957, when federal financial assistance for sewage construction was initiated, 55 percent of the value of new starts had been put in place in the same year. But with each increase in aggregate construction activity, the backlog of works under construction and works for which funds have been granted by construction has not yet started has increased.

## Expansion of Construction Activity

Another limiting force for the supply capability is the phased expansion of the wastewater facilities construction sector. This construction sector, like many economic sectors, contains numerous institutional constraints which may inhibit the ability to expand to meet the indicated demand. The recent trends in the expansion of construction activity in the municipal wastewater sector are shown in Table 12, where the six-year growth rate in construction activity is slightly over 28 percent in current dollars or 22 percent in constant dollars. The trend in recent years has been one of increasing activity; nevertheless to reduce the backlog and to keep pace with the planned construction activity indicated by the survey would require an unprecedented increase in construction activity.

If the historical trend in new construction activity in this sector maintains this 28 percent growth pattern (cf. Table 12), then Table 13 shows the projected activity in the next five years to be $18.9 billion. However, if the inflation rate is held down and the trend is more nearly like the years 1965 to 1970, then the rate of growth in construction activity would be 25 percent and projected starts would amount to $17.4 billion.

The survey results state that $18.1 billion in 1971 dollars is planned in construction activity in the next five years. Add to this the value of projects pending construction of $3.4 billion, and the survey estimates that total new starts in construction will be $21.5 billion through 1976. Table 13 of growth figures indicates that such activity is highly unlikely. Also the survey states that $5.28 billion is planned for 1972 and $9.28 billion for 1973 to 1974. To accommodate this level of activity the

## TABLE 12

## FEDERALLY-ASSISTED STARTS IN CONSTRUCTION OF MUNICIPAL WASTE TREATMENT FACILITIES

| | | Percent Increase, Year to Year | | |
|---|---|---|---|---|
| Year | Millions | Gross | Inflation[1] | Net |
| 1965 | 365.0 | | | |
| 1966 | 489.6 | 34.1 | 3.9 | 30.2 |
| 1967 | 397.0 | -18.9 | 2.9 | -21.8 |
| 1968 | 671.0 | 69.0 | 2.8 | 66.2 |
| 1969 | 936.9 | 39.6 | 7.3 | 32.3 |
| 1970 | 1360.7 | 45.2 | 7.8 | 37.4 |
| 1971 | 1700.0[2] | 24.9 | 15.0 | 9.9 |
| TOTAL | 5950.2 | | | |

---

[1] Source: Sewer and Sewage Treatment Plant Construction Index, Environmental Protection Agency.

[2] Twelve-month estimate.

## TABLE 13

## PROJECTED FEDERALLY-ASSISTED STARTS IN CONSTRUCTION OF MUNICIPAL WASTE TREATMENT FACILITIES

($ Millions)

| Year | 28 Percent Growth | 25 Percent Growth |
|---|---|---|
| 1971 | 1700.0 | 17.00.0 |
| 1972 | 2176.0 | 2125.0 |
| 1973 | 2788.0 | 2652.0 |
| 1974 | 3468.0 | 3315.0 |
| 1975 | 4607.0 | 4148.0 |
| 1976 | 5848.0 | 5185.0 |
| Total for: 1972-1976 | 18,887.0 | 17,425.0 |

construction industry would be required to nearly double annually or the build-up in work obligated but not under construction would continue.

On the other hand, the evaluation model estimate of $14.3 billion plus the $3.4 billion in pending projects adds up to $17.7 billion of planned construction activity for the next five years. This estimate assumed 7.5 percent inflation during that period and compares favorably with the historical trend assuming a 25 percent growth rate.

Thus the evaluation model is seen to be a more accurate indicator of investment needed in the municipal waste treatment area because it corresponds to both what has happened in the past and what might reasonably be expected to occur in the future. However, the weaknesses of demand modeling should be noted. It fails to reflect some components of demand which are not known precisely enough to distinguish qualitative shifts readily. Such shifts are the ratio of plant costs to ancillary costs; depreciation rates for interceptors, outfalls, pumping stations; and the loss of sunk capital through accelerated replacement and inadaptability of existing plants to higher degrees of treatment. Also, the composition of the backlog requirements, if not fully reported in the Municipal Waste Inventory, would also bias the backlog calculation.

## Conclusion

An assessment of needs should estimate the investment intentions of municipalities. In so doing, a precise account of planned construction activity should be taken so as to exclude expectation of such activities which have a low probability of actually being initiated. Such an assessment involves a tally of communities' demands, i.e. activities or projects required to meet environmental regulations and standards. A study of the supply, i.e. of what the industry is capable of constructing, is also involved. Both demand and supply considerations must be included to obtain a reliable projection of the necessary monies for investment in this sector. The preceding analysis demonstrates that the results of the model seems to accommodate both of these interacting forces of supply and demand, thus the figure of $14.5 billion is likely to represent planned construction activity during the FY 1972-1976 period. Next year a complete analysis of both supply and demand phenomena will be presented.

## Additional Survey Results for Communities Greater Than 10,000

### Relation of Construction to Regulatory Requirements

The responding municipalities were requested to indicate the reason for planning the construction reported. Table 14 shows, in summary form, the cost of constructing required facilities and the associated requirements to be fulfilled. It should be noted that approximately 83 percent of the costs are (nearly) equally distributed among three requirements, because of (a) locally developed plans, (b) State-approved implementation schedules, and (c) federally-approved water quality standards implementation plans.

Approximately $220 million in construction is to be initiated because of more stringent federally-approved water quality standards, and over $2.1 billion in construction is required because of enforcement procedures and/or State and federal court orders.

### Description of Facilities

Table 15 summarizes the survey results of needed facilities for the five-year period, by description and type. The details are discussed below.

1. New vs. Modified Works
   Summaries of the responses on the type of construction planned indicated that approximately 58 percent of the expected expenditures are for the construction of new facilities and 42 percent for modifications and improvements. As shown in Table 15, most of the modifications are for the purpose of increasing plant capacities and treatment levels.

2. Plants vs. Ancillary Works
   Approximately 53 percent (or $7.4 billion) of the cost of needed facilities is for the construction of new or improved plants and 41 percent (or $5.7 billion) is for ancillary works, such as pumping stations, interceptors, and outfall sewers. The remaining 6 percent is for projects involving individual plant elements (e.g. sludge processing and disposal operations and disinfection) and nutrient removal facilities. Of the approximately $5.7 billion to be used in the construction of ancillary works, about $3.7 billion is for interceptor sewers.

3. Level of Treatment
   An examination of the costs associated with the various levels of treatment indicates that of the estimated $7.4 billion for the construction of new and improved plant facilities, approximately 5.5 percent (or $405 million) is for primary treatment

## TABLE 14

## ESTIMATED COST OF CONSTRUCTION IN ACCORDANCE WITH REGULATORY REQUIREMENTS[1,2]

| Requirements | Estimated Cost of Facilities To Be Constructed ($ Billion) | Percent |
|---|---|---|
| Locally Developed Plan[3] | 3.721 | 27.0 |
| State Approved Implementation Schedule | 3.883 | 28.2 |
| Federal Approved Water Quality Standards Implementation Plan | 3.799 | 27.6 |
| FY '71 More Stringent Federally Approved WQS | .221 | 1.6 |
| Federal Enforcement Procedures or Actions | 1.251 | 9.1 |
| State Court Order | .781 | 5.7 |
| Federal Court Order | .104 | .8 |
| Total | 13.760 | |
| Facilities on which no requirement data submitted | .254 | |
| | 14.014 | |

---

[1] Based on survey of needs of municipalities with population of 10,000 or more for period FY-72-76.

[2] Excludes combined sewer overflow control facilities.

[3] With few exceptions, most of the projects identified with this requirement are being planned or developed in conformance with anticipated Federal and State Standards.

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## TABLE 15

## COST SUMMARY OF NEEDED FACILITIES BY DESCRIPTION AND TYPE[1]

($ Million)

| | TYPE | | | | | |
|---|---|---|---|---|---|---|
| Description | New Facility | Modification[2] | Increase In Capacity | Increase In Treatment Level | Increase In Treatment Level and Capacity | Total |
| Primary | 108.0 | 35.5 | 253.3 | 1.0 | 9.0 | 406.8 |
| Intermediate | 4.8 | 2.3 | 22.6 | 52.3 | 14.1 | 96.1 |
| Secondary | 1512.0 | 231.2 | 731.0 | 876.9 | 1297.5 | 4648.6 |
| Tertiary | 665.1 | 10.8 | 118.3 | 620.6 | 846.1 | 2260.9 |
| Nutrient Removal | 270.6 | 1.6 | 2.4 | 17.4 | 33.4 | 325.4 |
| Plant Elements | 281.2 | 126.3 | 69.9 | 31.0 | 67.6 | 576.0 |
| Ancillary Works | 5208.0 | 58.0 | 331.0 | 15.2 | 88.0 | 5700.2 |
| Totals | 8049.7 | 465.7 | 1528.5 | 1614.4 | 2355.7 | 14014.0 |

---

[1] For period FY-1972-76.

[2] No increase in capacity or treatment.

facilities; 1.3 percent (or $96 million) for the intermediate levels of treatment; 62.7 percent (or $4.647 billion) for secondary; and 30.5 percent (or $2.26 billion) for tertiary treatment facilities. Table 14 shows a State-by-State breakdown of needs for tertiary treatment facilities. It was found that 35 percent

of the cost of tertiary needs are reported in the States of Illinois (22 percent) and Maryland (13 percent). California, Florida, Michigan, New York, Ohio, and Virginia each reported needs of over $100 million.

4. Nutrient Removal--Phosphate and Nitrate
The estimated cost of facilities to be added to existing or proposed plants for nutrient removal is $325 million. Of this $148 million is for phosphates and $177 million is for nitrates. Seventy-five percent of the phosphate removal costs and 45 percent of the nitrate removal costs are projected for municipalities located in the Great Lakes Region. A State-by-State breakdown of needs is presented in Table 16.

5. Industrial Waste
Responding municipalities were requested to give the percentage of the effluent which, based on flow, can be attributed to industrial waste. Based on the number of need items, 46 percent showed no industrial waste component; for 43 percent of the needs, the percentage of industrial wastes (based on flows) ranged from one to 30 percent; the remaining 11 percent were in the 31 percent to 100 percent range. The summary result of applying the obtained percentages to the cost of projects involved indicates that approximately $2.17 billion of the $14.0 billion in construction proposed for municipalities serving 10,000 or more persons during the next five-year period is for the purpose of alleviating pollution from industrial sources.

6. Operation of Proposed Facilities
Expected facility operation dates and associated costs for the reporting municipalities are summarized in Table 17. In addition to these, as of November 1, 1971, there were $4.6 billion worth of federally-assisted projects under construction and another $3.4 billion in the preconstruction stages on which grant commitments had been made.

## User Charges

Table 18 summarizes the responses to the inquiry regarding the method upon which the user charge is based and the year the present usage rate was established. Fifty-four percent of the municipalities indicated "hydraulic volume" as the basis for charging and 17 percent "both volume and quality". Nearly 29 percent indicated the use of methods other than those identified in the survey.

TABLE 16

# ESTIMATED COST OF TERTIARY TREATMENT, NITRATE AND PHOSPHATE REMOVAL FACILITIES PLANNED FOR CONSTRUCTION DURING FY 1972-1976, BY MUNICIPALITIES WITH OR SERVING POPULATIONS OF 10,000 OR MORE

($ MILLION)

| | Tertiary Treatment | Nitrate Removal | Phosphate Removal |
|---|---|---|---|
| TOTALS | 2,260.24 | 176.79 | 148.35 |
| Alabama | | | |
| Alaska | | | |
| Arizona | | | |
| Arkansas | 14.80 | | |
| California | 113.46 | | |
| Colorado | 3.70 | | |
| Connecticut | 8.20 | | |
| Delaware | | | |
| Dist. of Columbia | 31.68 | 77.01 | |
| Florida | 157.35 | .50 | .50 |
| Georgia | 37.86 | | |
| Hawaii | | | |
| Idaho | | | |
| Illinois | 497.59 | 54.77 | 57.25 |
| Indiana | 85.81 | 3.06 | 14.02 |
| Iowa | 14.65 | | |
| Kansas | 7.02 | | |
| Kentucky | 11.17 | .36 | |
| Louisiana | | | |
| Maine | | | |
| Maryland | 292.66 | | .55 |
| Massachusetts | 47.70 | | |
| Michigan | 112.24 | 7.15 | 22.18 |
| Minnesota | 11.64 | | 3.14 |
| Mississippi | | | |
| Missouri | 2.83 | | |
| Montana | | | |
| Nebraska | 7.40 | | |
| Nevada | | | |
| New Hampshire | 6.50 | | |
| New Jersey | 86.89 | | |
| New Mexico | 11.85 | | |
| New York | 108.66 | 7.78 | 28.24 |
| North Carolina | 45.12 | | 1.62 |
| North Dakota | | | |
| Ohio | 184.05 | 3.66 | 10.20 |
| Oklahoma | 37.31 | | |
| Oregon | 5.27 | | |
| Pennsylvania | 62.45 | 12.00 | 4.86 |
| Rhode Island | | | |
| South Carolina | | | |
| South Dakota | | | |
| Tennessee | 5.38 | | |
| Texas | 89.56 | | |
| Utah | 15.00 | | |
| Vermont | | | |
| Virginia | 124.20 | | 1.55 |
| Washington | .70 | | |
| West Virginia | | | |
| Wisconsin | 16.54 | 10.50 | 4.24 |
| Wyoming | | | |
| Guam | | | |
| Puerto Rico | 3.00 | | |
| Virgin Islands | | | |

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## TABLE 17

## EXPECTED YEAR OF OPERATION OF PROJECTS TO BE INITIATED IN FISCAL YEARS 1972-76 IN MUNICIPALITIES WITH OR SERVING POPULATIONS OF 10,000 OR MORE

| Year Of Facility Operation | Estimated Cost Of Facilities ($ Millions) |
|---|---|
| FY-1972 | 120 |
| FY-1973 | 1,235 |
| FY-1974 | 2,932 |
| FY-1975 | 3,026 |
| FY-1976 | 3,292 |
| FY-1977 | 2,152 |
| FY-1978 + | 1,257 |
| Total | 14,014 |

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## TABLE 18

## NUMBER OF MUNICIPALITIES[1], HAVING CONSTRUCTION NEEDS IN THE FY 72-76 PERIOD, WITH USER CHARGES, AND THE METHOD UPON WHICH CHARGE BASED AND YEAR RATE ESTABLISHED

| Year Rate Established | Basis of Use Charge<br>Hydraulic Volume | Quantity of BOD | Quantity of Solids | Both BOD & Solids | Both Volume & Quality | Other |
|---|---|---|---|---|---|---|
| Prior to 1941 | 6 | 0 | 0 | 0 | 0 | 9 |
| 1941 - 1950 | 17 | 0 | 0 | 0 | 3 | 13 |
| 1951 - 1960 | 148 | 0 | 0 | 1 | 23 | 56 |
| 1961 - 1965 | 121 | 1 | 0 | 1 | 40 | 70 |
| 1966 - 1970 | 407 | 2 | 0 | 3 | 118 | 162 |
| 1971 | 150 | 0 | 0 | 3 | 78 | 83 |
| No years indicated | 30 | 0 | 0 | 0 | 14 | 73 |
| Total | 879 | 3 | 0 | 8 | 276 | 466 |

---

[1] With or serving populations of 10,000 or more.

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## Additional Employee Requirements

Approximately 12,700 additional employees are reported to be needed in the municipalities surveyed, as a result of the construction to be initiated through FY 1976. Of these, 16 percent are for professional positions, 65 percent for operations and maintenance needs, and the remaining 19 percent are required to fill administrative support-type jobs. About 5,700 or 45 percent of the employees will be needed in FY 1975 and FY 1976. This information is summarized in Table 19. It is of interest to note that in the March 1972 EPA Manpower Report to Congress the number of additional employees needed through FY 1976 was estimated at 13,900. This was based on information from a different set of sources.

## Program Accomplishments in Municipal Waste Treatment Facilities

In evaluating the progress being made in the nation's water pollution abatement effort it is important to report trends and current levels in waste production and treatment. The report presents accomplishment data for the years 1968-1972. The emphasis of this report will be upon the municipal sector since this is the area in which the greatest amount of federal activity has been concentrated over the past years.

The data for 1968-1970 was obtained from the General Discharge File maintained by the Office of Water Programs. The records for 1971 and 1972 are based partially on data from the file and projections based on a trend analysis of existing data. The results of this analysis are included in Table 20. The table presents accomplishments in terms of population sewered and increases in wastes treated. The table also indicates the level of treatment and the decrease in population receiving primary treatment. The percentage of population receiving treatment has not significantly increased.

The discussion of program accomplishments will be more extensively analyzed in the next year's cost study. The extent to which the projected expenditures through 1976 will effect these accomplishment measures will be analyzed and presented along with action accomplishments for the period.

## TABLE 19

## ESTIMATED NUMBER OF EMPLOYEES NEEDED TO MAN FACILITIES,[1] PROPOSED FOR CONSTRUCTION DURING FY 72-76, AND FISCAL YEAR FACILITIES EXPECTED TO BE OPERATIONAL

| | Categories of Employment | | | | |
|---|---|---|---|---|---|
| Fiscal Year | Professional | Operation and Maintenance | Other | Totals | Percent |
| 1972 | 51 | 139 | 36 | 226 | 1.8 |
| 1973 | 350 | 1,207 | 401 | 1,958 | 15.5 |
| 1974 | 494 | 3,323 | 687 | 3,504 | 27.6 |
| 1975 | 461 | 1,972 | 535 | 2,968 | 23.4 |
| 1976 | 354 | 1,343 | 348 | 2,045 | 16.1 |
| 1977 | 189 | 666 | 225 | 1,080 | 8.5 |
| 1978 | 75 | 371 | 130 | 576 | 4.6 |
| 1979 | 33 | 191 | 34 | 258 | 2.0 |
| 1980 + | 10 | 38 | 13 | 61 | .5 |
| Totals | 2,017 | 8,250 | 2,409 | 12,676 | 100.0 |
| Percent | 15.9 | 65.1 | 19.0 | 100.0 | |

---

[1] For municipalities with or serving populations of 10,000 or more.

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## TABLE 20

## PROGRAM ACCOMPLISHMENTS

| | 1968 | 1969 | 1970 | 1971[1] | 1972[1] |
|---|---|---|---|---|---|
| Sewered Population (millions, persons) | 140 | 144 | 148 | 152 | 156 |
| Waste Strength gross wastes treated by municipal plants (million/pounds/year BOD's) | 14,137 | 14,773 | 15,438 | 16,133 | 16,859 |
| Level of Treatment (Percent) | | | | | |
| Sewered Population Untreated | 7 | 7 | 6 | 6 | 5 |
| Sewered Population Primary | 31 | 30 | 28 | 25 | 24 |
| Sewered Population Secondary | 62 | 63 | 66 | 68 | 70 |
| Sewered Population Advanced | <1 | <1 | <1 | <1 | <2 |

---

[1] Based upon Historical Growth Trends 1962-1970.

# ENVIRONMENTAL AND ECONOMIC BENEFITS AND COSTS RELATED TO VARIOUS WATER POLLUTION ABATEMENT STRATEGIES[1]

Attention to the marginal benefits and costs of various treatment levels is necessary to insure that the water pollution goals sought are defensible in terms of their net benefit to society. The subsequent analysis of the marginal costs and benefits to attention levels of treatment suggests:

- Because costs accelerate rapidly as higher levels of treatment are achieved, the total cost of meeting very high levels of treatment approaching zero discharge could be many times those required to meet current water quality standards.
- The improvement in beneficial uses of waters from such expenditures are likely to be modest compared to the costs. All the pollution parameters of concern have not yet been converted to water quality standards so that any current estimates are likely to be low.
- A number of adverse environmental impacts would occur such as higher energy consumption and solid waste problems.
- Large resources devoted to achieving small increases in water quality benefits have the effect of withdrawing resources from other environmental efforts or other national priorities.

## Abatement Costs

### Rising Marginal Costs

Although control techniques and costs vary greatly by source, there are basic operational and technical factors which result in similar control costs curves for most sources. These control costs increase rapidly as higher levels of control are achieved.

The principle levels of municipal waste treatment are usually described as:

- secondary treatment which removes 85-90 percent of oxygen-demanding wastes (BOD) and suspended solids by physical and biological treatment methods;
- chemicals addition to secondary removes 90-95 percent of BOD and suspended solids along with 80-90 percent of phosphates;

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[1] Summary of "Environmental and Economic Benefits and Costs Related to Various Water Pollution Abatement Strategies", paper prepared by EPA and CEQ.

- tertiary treatment[2] which removes 95-99 percent of BOD, suspended solids and other pollutants, ranging in cost and treatment levels from two-stage line clarifications, activated carbon adsorption, to reverse osmosis; and
- zero discharge which removes all pollutants and may be accomplished by complete distillation or wastewater recycling.

Industrial treatment levels are often described similarly, although the types of wastes and abatement levels can be quite different. Also, abatement from industrial wastes and abatement levels can be quite different. Furthermore, abatement from industrial wastes can in part be accomplished by production process changes and improved internal management, as well as, end-of-the-line treatment.

### Rising Incremental Costs

Figure 1 is illustrative of cost curves for both municipal and industrial water pollution control. Because industry has more alternatives which can be used to achieve pollutant reduction, the curve is not completely accurate. It is probable that in most industries, the costs of abatement would be less at the lower levels of reduction because process changes and better waste management be employed. But at higher levels of control, additional waste treatment will be required as represented by the cost curve shown (cf. Figure 1). In other words, the difference between control costs at high levels over those at lower levels will be greater than that shown in Figure 1.

These rapidly accelerating costs are illustrated in Table 1. As the table indicates, the cost of reducing the last increments of pollutants are much greater than lower levels of treatment. For example, a 10 percent increase in treatment--from 85 to 95 percent--would raise investment costs by 50 percent; while another 3 percent increase would raise costs by the same amount.

### Total Costs

Table 2 illustrates the capital, operating, and annualized costs that would be incurred during 1971-1981 to achieve levels of effluent reductions for municipalities.

Table 3 illustrates the capital, operating, and annualized costs that would be incurred during 1971-1981 to achieve various levels of effluent reductions for industry.

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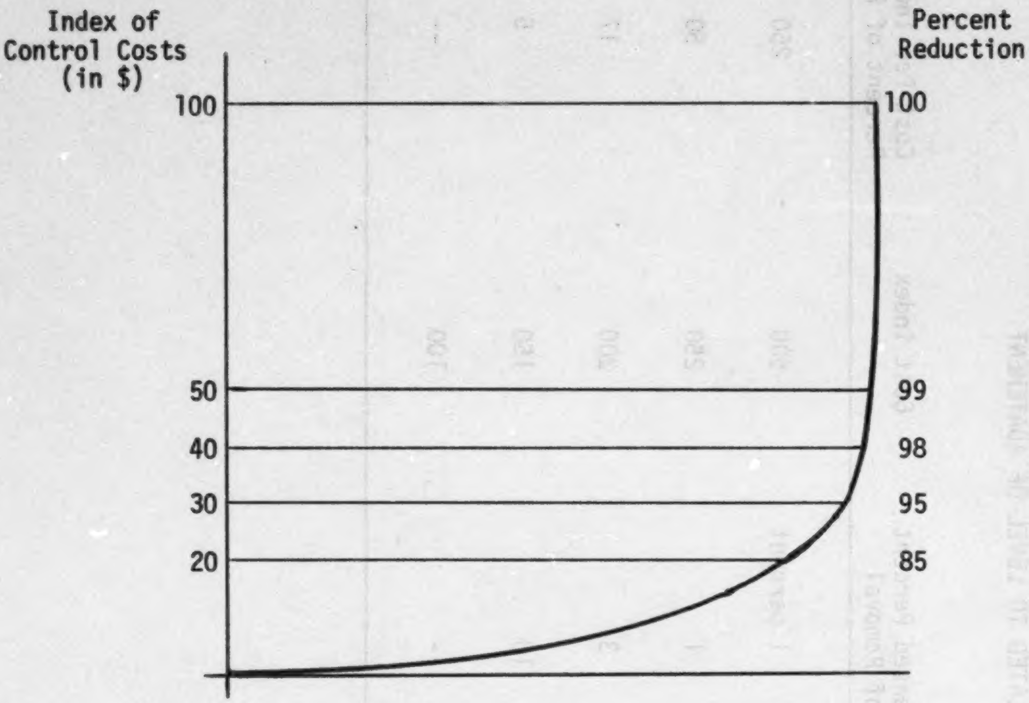
[2] In some cases, land disposal of liquid effluents may also be used. This method is approximately equivalent to tertiary treatment. EPA has several studies currently being conducted in this area and is cooperating in a pilot project in Muskegon County, Michigan. Though not applicable throughout the nation, in appropriate areas the costs would seem to be nearly equivalent to the alternative treatment methods.

FIGURE 1

TOTAL CONTROL COSTS AS A FUNCTION OF EFFLUENT CONTROL LEVELS



Source: Interior 1965 Saline Water Conversion Study
Young and Pisano: "Nonlinear Programming Applied to Regional Water Resource Planning".

FWPCA: Cost of Clean Water, 1968, Volume I.

FWQA: Cost of Clean Water, 1970, Volume IV.

# TABLE 1

## INDEX OF POLLUTION CONTROL INVESTMENT COSTS RELATED TO LEVEL OF ABATEMENT

| Level of Removal | Increased Percent of Removal | Cost Index | Cost Per Increased Percent of Removal |
|---|---|---|---|
| 100 percent | 1 percent | 500 | 250 |
| 99 | 1 | 250 | 50 |
| 98 | 3 | 200 | 17 |
| 95 | 10 | 150 | 5 |
| 85 | -- | 100 | -- |

## TABLE 2

## MUNICIPAL COSTS

(Dollars in Billions)

| Level of Removal | Capital Investment Expenditures[1,2] | Operating Costs | Total Expenditures | Annualized Costs in 1981[3] |
|---|---|---|---|---|
| 100%<br>(Zero Discharge) | 59.5 | 82.3 | 141.8 | 10.6 |
| 80% @ 95-99%<br>20% @ 100% | 29.0 | 43.4 | 72.4 | 7.0 |
| 95-99%<br>(High Levels of Chemical and Physical Treatment) | 21.3 | 33.6 | 54.9 | 4.2 |
| 85-90%<br>(Roughly Current Program) | 10.6 | 16.2 | 26.8 | 2.0 |

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[1] Assumes investment put in place by 1981.

[2] Includes only treatment costs. Interceptors and other facilities related to treatment and eligible for federal grants would raise each of the figures in this column by $12.0 billion.

[3] Depreciation over 25-year life, interest at 6.0 percent, and operating costs in 1981.

## TABLE 3

## INDUSTRIAL COSTS

(Dollars in Billions)

| Level of Removal | Capital Investment Expenditures[1] | Operating Costs | Total Expenditures | Annualized Costs in 1981[2] |
|---|---|---|---|---|
| 100%<br>(Zero Discharge) | 35.0 | 139.7 | 174.7 | 10.5 |
| 80% @ 95-99%[3]<br>20% @ 100% | 18.2 | 66.7 | 84.9 | 5.4 |
| 95-99%<br>(High Levels of Chemical and Physical Treatment) | 14.0 | 49.9 | 63.9 | 4.2 |
| 85-90%<br>Roughly Current Program) | 7.0 | 27.0 | 34.0 | 2.1 |

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[1] Assumes investment put in place by 1981.

[2] Depreciation for 2 years, interest at 8.0 percent, and operating costs in 1981.

[3] Interpretation of goals in Senate Public Works Committee report.

It should be noted that the ratio of operating costs to capital costs is roughly four to one for industrial waste treatment while it is about one to one-and-a-half for municipal treatment. In both cases, this illustrates the heavy commitment to operating as well as capital costs that result from higher levels of abatement.

Table 4 summarizes the total costs to society of achieving the various levels of pollutant reduction.

### Benefits Achieved at Various Levels of Abatement

The ultimate goal of any pollution control program is to achieve certain environmental quality objectives. These goals have traditionally been set forth in standards of quality that deal with preventing adverse effects or achieving certain beneficial uses. For example, higher water quality provides such beneficial uses as water supply, recreation, and fish and wildlife. The least costly method meeting these objectives is to tailor effluent reductions to meet those ambient objectives. To the extent the effluent reductions are more stringent than those which are required, excessive costs are incurred needlessly. This is particularly true at high control levels where control costs escalate very rapidly.

In order to assess the level of improvements in ambient conditions, it is necessary to understand the general relationship between ambient improvements, their associated benefits, and the costs to achieve them. A study of cost and benefits in the Delaware Estuary performed by the Federal Water Pollution Control Administration illustrates the relationship of benefits to costs.

| Dissolved Oxygen (mg/l)* | Index of Costs of Control | Index of Recreational Benefits |
|---|---|---|
| 6.5 | 575 | 128 |
| 5.5 | 320 | 115 |
| 5.0 | 150 | 105 |
| 4.0 | 100 | 100 |

*Approximate values, although this factor and others varied by area within the estuary.

These data are presented to indicate the rapidly increasing marginal costs at higher levels of abatement and the lesser increases in benefits at such levels of control. The costs for the highest levels of dissolved oxygen assume control between secondary and tertiary treatment. Full tertiary treatment, i.e. a form of best available technology, would escalate the cost greatly with very little increase in benefits. A total no-discharge requirement would push the costs still higher.

The Delaware study is now nearly a decade old. EPA recognizes the paucity of information concerning economic measures of benefits and is making a

## TABLE 4

## TOTAL NATIONAL COSTS[1]

(Dollars in Billions)

| Level of Removal | Ten-Year Capital Expenditures | 20-25 Year Operating Costs | Total Expenditures | Annualized Costs in 1981 |
|---|---|---|---|---|
| 100% | 94.5 | 220.0 | 316.5 | 21.1 |
| 80% @ 95-99% | | | | |
| 20% @ 100% | 47.2 | 110.1 | 157.3 | 12.4 |
| 95-99% | 35.3 | 83.5 | 118.8 | 8.4 |
| 85-90%<br>(Roughly Current Program) | 17.6 | 43.2 | 60.8 | 4.1 |

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[1] Excludes $12.0 billion costs for intercepting sewers.

concerted effort to refine costs and develop methodologies for quantifying benefits. Currently EPA is participating in an effort by the Water Resource Council to develop guidelines for cost-benefit analyses.

The effect of imposing large costs to achieve small increases in water quality benefits will have the effect of withdrawing resources from other environmental efforts or other national priorities. For example, it will be necessary to devote large sums of money to control air pollution, strip mining, oil spills and to achieve other environmental goals. Also large resources will be necessary to meet other high priority national goals. The extent to which inordinately high amounts of money are devoted to small improvements in water quality will cause other national priorities to suffer.

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